

ACTA RADIOLOGICA

FOUNDED IN 1921 BY GÖSTA FORSSELL

OFFICIAL ORGAN OF THE RADIOLOGICAL SOCIETIES OF DENMARK, FINLAND, NORWAY AND SWEDEN

EDITOR ERIK LINDGREN

ASSISTANT EDITOR ULF RUDHE

ASSOCIATE EDITORS

Radiodiagnosis OLLE OLSSON

Radiotherapy LARS-GUNNAR LARSSON

Radiophysics KURT LIDEN

Radiobiology BORJE LARSSON

EDITORIAL BOARD

Denmark S. KAAE G. THOMSEN

Finland L. R. HOLSTI P. VIRTAMA

Norway E. POPPE J. FRIMANNS DAHL

Sweden O. BARTLEY L. G. LARSSON

DIAGNOSIS

INDICES to Vol 10 (1970)

January March May July September November

Contents of Volume 10 — DIAGNOSIS

Normal size of the internal carotid middle cerebral and anterior cerebral arteries By T O GABRIELSEN and T GREITZ	1
Skull size and ventricular dilatation in subdural hygroma in infants By S CRONQVIST and H O ERSING	11
Neurotoxicity of roentgen contrast media — Study of the blood brain barrier in the rabbit following selective injection of contrast media into the internal carotid artery By P G JEPSSON and I OLIN	17
Arteriographic appearances of phaeochromocytomas By L O LANNER and M ROSENCRANTZ	35
Microangiography of the renal vessels in rabbit — Comparison of different methods By H WENDELIN and I LINDGREN	49
Atypical roentgen appearances of the lung in hyaline membrane disease of the newborn By U RUDHE F R MARGOLIN and B ROBERTSON	57
Residual contrast medium in the intestines and side effects during cholecystography — A comparison between some contrast media in current use and a new medium By S ERIASSON and G F SALTZMAN	69
Cineroentgen equipment for small objects By O MATTSOY	76
Angiography in intracranial cavernous hemangiomas By H BOGREN G SJALANDER and I WICKBOM	81
Fibromuscular hyperplasia of the carotid arteries By P E ANDERSEN	90
Embohc complications in cerebral angiography with the catheter technique By S CRONQVIST H O ERSING and E PALACIOS	97
Roentgenologic angulation measurement in supracondylar fractures of the femur By O LINDAHL and A MOVIN	108
Motility of diaphragm in children with bronchial foreign bodies By G THEANDER	113
Mesenteric adenitis in childhood simulating intussusception By N HAJDU	130
Histologic staining of contrast filled blood vessels in microangiographed tissues By M KORMANO	138
Angiographic demonstration of rupture of the spleen By B LUNDSTROM	145
Effect on erythrocytes of large doses of contrast medium in clinical angiocardiology By L BJORK	151
Book reviews	155
Angiographic diagnosis of tumours arising from the pancreatic islets By E BORJSEN and L SAMUELSSON	161
Carotid angiography in cluster headache By K EKBOM and T GREITZ	177
Sialography of the sublingual gland — A modified technique enabling subtraction By B LILIEQUIST and U WELANDER	187

Transcaval injection of the portal vein — A preliminary report on a new technique By M HAVERLING C O OVENFORS and S DAHLGREN	193
Retinal and cerebral fat emboli following lymphography with oily contrast media By K E RASMUSSEN	199
Fibromuscular hyperplasia in children By P E ANDERSEN	203
Balloon catheters and their percutaneous insertion into the vascular system By M HAVERLING	209
Arteriovenous fistulae secondary to renal biopsy — An experimental study in the rabbit By L EKLUND	218
Roentgenologic diagnosis of polycystic kidney and medullary sponge kidney By B I IVERMARK C LAGERGREN and N LINDVALL	225
Immediate centering and tomographic cut localization by means of roentgen television By J FRIMAN DAHL and H B KJELL	236
L'artériographie après cathétérisme percutané par voie artérielle axillaire Par J F HUGUET et B NAVARRO	241
Simplified sensitometry By O MATTSOEN	252
Traumatic arterial spasm — An angiographic study in rabbits By J GOTTLIN and T OLIN	257
Position of the 'venous angle' in the median sagittal plane — A new topometrical method By F P PROBST	271
Aspiration biopsy diagnosis of neurogenous mediastinal tumours By S E DAHLGREN and C O OVENFORS	289
Routine abdominal radiology in periodic health examinations By H W GILLESPIE	299
Roentgenologic photometric method for bone mineral determinations By B EKMAN A G Ljungquist and U STERN	305
Synovial lesions in the adult hip joint in rheumatoid arthritis By W J WESTON	326
Experimental isotope renography as a means of localizing ureteric obstruction By I LINDGREN and P MAKELA	332
Double contrast cystography — A new contrast medium and a simplified technique By J T JENSEN	337
Non filling of the ventricular system in encephalography By S HOLM MOLLER	345
Topometric positions of 'venous angle' in intracranial expansive lesions By F P PROBST	353
Lymph node scanning with colloidal radioactive gold By S E HERTING P BUCHLER-FREDERIKSEN T JAGT and P JEPPESEN	359
Venous communications of the adrenal glands — Anatomic and circulatory studies By C G MIKAELOSON	369
Destruction of the odontoid process due to atlanto-axial pyogenic spondylitis By S AHLBACK and S COLLERT	394
Correction of the pelvis in bladder exstrophy — A radiographic analysis By P EDHOLM	401
Semi automatic construction and computer analysis of volume curves and pressure volume curves in left ventricular cineangiography By L BJORK	413

Phlebographic changes in arteriomegaly	
By M LEA THOMAS and M R ANDRESS	427
Diagnosis of fluid in the maxillary sinus	
By N CHIDEKEL C JENSEN A AXELSSON and N GREBELIUS	433
Elimination of blur in linear tomography	
By P EDHOLM and L QUIDING	441
Book review	448
Effect of local intraarterial administration of bradykinin and hydergine in obstructive arterial disease	
By U FRIKSON	449
Effect of dextran solutions on intravenous iodipamide toxicity	
By C G GROTH B LORSTROM and G F SALTZMAN	458
Experimental lymphography in cardiac arrest electrical ventricular fibrillation and deep hypothermia	
By A CÉLIS M A MENA and H DEL CASTILLO	465
Angiographic diagnosis of rejection and tubular necrosis in human kidney allografts	
By J HAUDE D H SLUSHER W W PRAFF and R L HACKETT	476
Hystero-graphy in intrauterine pregnancy and abortion — Report on three cases	
By M HONORÉ	489
Cystosarcoma phyllodes diagnosed by subcutaneous mammary phlebography	
By F P PROBST	494
Oral cholecystography — Experimental investigation and clinical comparison of 70-mm film and full scale radiography	
By R JENSEN and J HAUDE	499
Occurrence and course of thrombosis following prostatectomy — A phlebographic investigation	
By J BECKER S BORCSTROM and G F SALTZMAN	513
Scintillation camera and rectilinear scanner for detection of space-occupying intracranial lesions	
By M PEDERSEN and J HAASE	534
Roentgen examination of the facial canal	
By S BRUNNER and CHR BRAHE PEDERSEN	545
Cannula for injection of contrast medium in cerebral angiography	
By G WESTBERG	553
A safer enema nozzle	
By O MATTSOON	557

NORMAL SIZE OF THE INTERNAL CAROTID, MIDDLE CEREBRAL AND ANTERIOR CEREBRAL ARTERIES

by

TRYGVE O. GABRIELSEN and TORGNY GREITZ

The size of the internal carotid, middle cerebral and anterior cerebral arteries have been investigated by WOLLSCHLAEGER & WOLLSCHLAEGER (1966) in unselected cadaver brains as well as with carotid angiography performed during life. However, neither the angiographic nor the clinical diagnoses were given for the living subjects.

The present investigation has been made in an attempt to determine the normal size of the internal carotid, middle cerebral and anterior cerebral arteries.

Material and Methods The records of 4 402 carotid angiographies coded as normal during the fifteen year period 1950–1964 were screened in order to find as many normal examinations as possible. Of all these examinations, 4 139 had been performed at Serafimerlasarettet and 263, the more recent ones, in the Department of Neuroradiology at Karolinska sjukhuset.

Most of the cases were eliminated from the study either because of the history, or signs pointing to disease of the central nervous system other than epilepsy. An abnormal electro-encephalogram among the epilepsy cases was not regarded as a ground for exclusion. No case with abnormal neurologic signs or recent

From the Department of Neuroradiology (Director Prof T. Greitz), Karolinska Sjukhuset, Stockholm, Sweden. Submitted for publication 5 February 1969.

Phlebographic changes in arteriomegaly	
By M LEA THOMAS and M R ANDRESS	427
Diagnosis of fluid in the maxillary sinus	
By N CHIDEKEL C JENSEN, A AXELSSON and N GREBELIUS	433
Elimination of blur in linear tomography	
By P EDHOLM and L QUIDING	441
Book review	448
Effect of local intraarterial administration of bradykinin and hydergine in obstructive arterial disease	
By U ERIKSON	449
Effect of dextran solutions on intravenous iodipamide toxicity	
By C G GROTH B LORSTROM and G F SALTZMAN	458
Experimental lymphography in cardiac arrest electrical ventricular fibrillation and deep hypothermia	
By A CELIS M A MENA and H DEL CASTILLO	465
Angiographic diagnosis of rejection and tubular necrosis in human kidney allografts	
By J KAUDE D H SLUSHER W W PRAFF and R L HACKETT	476
Hysterothygraphy in intrauterine pregnancy and abortion — Report on three cases	
By M HONORE	489
Cystosarcoma phyllodes diagnosed by subcutaneous mammary phlebography	
By F P PROBST	494
Oral cholecystography — Experimental investigation and clinical comparison of 70-mm film and full scale radiography	
By R JENSEN and J KAUDE	499
Occurrence and course of thrombosis following prostatectomy — A phlebographic investigation	
By J BECKER S BOROSTROM and G F SALTZMAN	513
Scintillation camera and rectilinear scanner for detection of space occupying intracranial lesions	
By M PEDERSEN and J HAASE	534
Roentgen examination of the facial canal	
By S BRUNNER and CHR BRAHE PEDERSEN	545
Cannula for injection of contrast medium in cerebral angiography	
By G WESTBERG	553
A safer enema nozzle	
By O MATTSSON	557

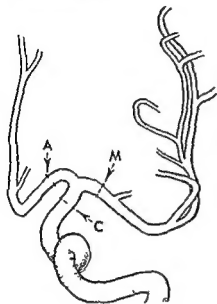


Fig 1

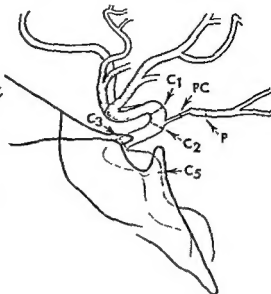


Fig 2

Fig 1 Diameters of the internal carotid, middle cerebral and anterior cerebral arteries, determined in anteroposterior roentgenograms of normal carotid angiographies

Fig 2 Various diameters of the internal carotid artery determined in lateral roentgenograms of normal carotid angiographies

were obtained by serial filming with a 10 by 12 inch Elema Schonander changer at 85 cm film-focus distance. The 10 by 12 inch Elema-Schonander cassette holder (LINDGREN 1947) and a film focus distance of 70 cm had been used for the 112 earlier examinations.

The measurements were carried out as follows. The diameter of the contrast-filled lumen was marked with a sharp lead pencil and the diameter measured with a transparent ruler to an attempted accuracy of one tenth of a millimeter. In order to determine the standard error of measurement, both writers in 50 of the 156 examinations, made two sets of measurements, all four sets independent of each other.

Measurements C, M and A were taken both from anteroposterior and half-axial views, in which the petrous ridge was projected below or above the roof of the orbit, C was the diameter of the internal carotid artery 5 mm proximal to its bifurcation into the anterior and middle cerebral arteries. The size of the middle cerebral artery (M) and, respectively, the anterior cerebral artery (A) were measured 5 mm beyond their origin (Fig 1). Measurements of the arterial

history of head injury or subarachnoid hemorrhage was included. A history of trigeminal neuralgia, migraine, and other types of headache, was considered acceptable. There were no clinical notes to suggest that angiography had ever been carried out during an acute attack of migraine.

If additional roentgenographic investigation or subsequent evidence revealed even probable central nervous system disease other than as specified above, such a case was excluded from the study, cases of relatively minor deformity or asymmetry of the skull were thus eliminated. Exclusion of angiographies performed under general anesthesia explains the absence of children in the series. Examinations with perivascular or subintimal injection of contrast medium were discarded.

Only studies of good technical quality, with at least one lateral and one frontal roentgenogram in the arterial phase, were included. Arterial measurements were often made from both anteroposterior and half-axial projections from the same carotid angiography. Cases of even minimal atherosclerosis involving the cerebral arteries, and those having known cerebral atrophy of either central or cortical type, were eliminated from the investigation.

One hundred and thirty-three cases, which passed all requirements for 'normality', also had normal encephalographies. In the remaining cases without pneumograms, the carotid angiographies were used for measurement only when careful scrutiny of the venous phase pointed to a normal size of the lateral ventricles.

These strict criteria permitted measurement of the arterial size to be performed in 156 angiographies from 72 males and 84 females, ranging in age from 13 to 69 years.

Number of	0—9	10—19	20—29	30—39	40—49	50—59	60—69 years
examinations	0	20	42	51	25	14	4

The clinical diagnoses in these cases are listed below according to frequency.

	Cases
Epilepsy	120
Trigeminal neuralgia	4
Migraine	10
Other types of headache	22

Although bilateral examinations were performed in some of the cases, only one examination (either right or left) per case was included in the study. All examinations had been carried out by direct percutaneous puncture of either the common carotid or the internal carotid arteries. The latest 44 angiographies

Table 1

Mean values for various diameters of normal cerebral arteries based on 156 normal carotid angiographies and no correction for sex and skull size

Measurement	Mean diameter	Standard deviation
M	3.82 mm	0.43 mm
A	3.02 mm	0.50 mm
C	4.57 mm	0.46 mm
C ₁	3.78 mm	0.43 mm
C ₂	4.08 mm	0.47 mm
C ₃	5.12 mm	0.63 mm
C ₄	5.80 mm	0.76 mm
C ₅	5.90 mm	0.73 mm
Siphon length	15.1 mm	2.45 mm

Table 2

Influence of sex and external biparietal diameter (W measured in cm) on the size of the internal carotid and middle cerebral arteries expressed in mm

Measurement	Male	Female
M	1.97 ± 0.118 W	1.78 ± 0.118 W
C	2.99 ± 0.100 W	2.81 ± 0.100 W
C ₂	4.56 ± 0.112 W	3.91 ± 0.112 W
M + C + C ₂	9.52 ± 0.330 W	8.50 ± 0.330 W

by performing measurements on test films that have also been measured by the observer whose data were used in this study.

The mean values obtained for the various arterial diameters in the total material, with no corrections made for sex and skull size, are presented in Table 1. The measurements for the posterior cerebral and posterior communicating arteries could be made in so few angiographies that the results of these were not included. Measurement C₆ could be performed in only 105 cases. The value for C₆ was practically the same in cases subjected to internal carotid artery puncture and in those subjected to puncture of the common carotid artery.

The statistical analysis (C₆ not included) revealed no significant correlation between the measured size of the cerebral arteries and the following variables: site of injection (internal against common carotid artery), side of injection, electroencephalographic findings, blood pressure, and age.

diameters were made on the lateral roentgenograms (Fig 2) at the following locations: the internal carotid artery 5 mm peripheral to its junction with the posterior communicating artery (C_1), the internal carotid artery just proximal to the junction with the posterior communicating artery (C_2), the internal carotid artery at the level of the tuberculum sellae (C_3), the internal carotid artery just proximal to its bend at the posterior aspect of the cavernous sinus (C_5), the internal carotid artery at the level of the atlas (C_7), the posterior communicating artery 5 mm posterior to its connection with the internal carotid artery (PC), and the posterior cerebral artery 5 mm peripheral to its junction with the posterior communicating artery (P). Measurement C_1 occasionally had to be made less than 5 mm peripheral to the posterior communicating artery when this part of the internal carotid artery was unusually short. The length of the carotid siphon from the tuberculum sellae was also measured.

The data were studied statistically in a series of multiple regression analyses performed with an automatic computer. The initial analysis was carried out by considering the sum of three measurements ($M + C + C_5$) as one dependent variable in order to make a preliminary exploration and to decrease the adverse effect of measurement errors. Investigation was made of the manner in which this dependent variable was affected by the simultaneous variation of background variables, such as age and sex, clinical diagnosis, EEG findings, systolic and diastolic blood pressure, skull width and skull length, internal or external carotid injection, injection on left or right side, serial or no serial filming, and the projections used. In this analysis the dependent variable ($M + C + C_5$) was studied in relation to each background independent variable in order to judge the amount of dependence when other independent variables were held constant. In the next stage, the relationships of all single artery measurements (A , M , C , C_1 , C_2 etc) to those variables that seemed important in the initial exploration were investigated.

Results

The measurements analysed by multiple regression were all performed by the same observer, whose standard error of measurement relating to a single determination was estimated to be 0.127 mm for C , 0.124 mm for M , 0.146 mm for C_1 and 0.122 mm for C_2 . These standard errors were somewhat larger for the other observer. The figures indicate a very good reproducibility as regards repeat measurements on the same film. On the other hand, there is an indication of systematic differences between observers amounting to as much as 0.15 mm. Anybody using the figures now given as a standard should be aware of this source of error. A possibility of making adjustments for errors of this type exists.

Table 1

Mean values for various diameters of normal cerebral arteries based on 156 normal carotid angiographies and no correction for sex and skull size

Measurement	Mean diameter	Standard deviation
M	3.82 mm	0.43 mm
A	3.02 mm	0.50 mm
C	4.57 mm	0.46 mm
C ₁	3.78 mm	0.43 mm
C ₂	4.08 mm	0.47 mm
C ₃	5.12 mm	0.63 mm
C ₄	5.80 mm	0.76 mm
C ₅	5.90 mm	0.73 mm
Siphon length	15.1 mm	2.45 mm

Table 2

Influence of sex and external biparietal diameter (W measured in cm) on the size of the internal carotid and middle cerebral arteries expressed in mm

Measurement	Male	Female
M	1.97 ± 0.118 W	1.78 ± 0.118 W
C	2.99 ± 0.100 W	2.81 ± 0.100 W
C ₁	4.56 ± 0.112 W	3.91 ± 0.112 W
M + C + C ₁	9.52 ± 0.330 W	8.50 ± 0.330 W

by performing measurements on test films that have also been measured by the observer whose data were used in this study.

The mean values obtained for the various arterial diameters in the total material, with no corrections made for sex and skull size, are presented in Table 1. The measurements for the posterior cerebral and posterior communicating arteries could be made in so few angiographies that the results of these were not included. Measurement C₆ could be performed in only 105 cases. The value for C₆ was practically the same in cases subjected to internal carotid artery puncture and in those subjected to puncture of the common carotid artery.

The statistical analysis (C₆ not included) revealed no significant correlation between the measured size of the cerebral arteries and the following variables: site of injection (internal against common carotid artery), side of injection, electroencephalographic findings, blood pressure, and age.

The electroencephalographic findings were analyzed not only as normal against abnormal but also in sub groups as focal versus non-focal and lateralizing versus non-lateralizing. Blood pressure data were analyzed separately in terms of systolic and diastolic pressures as well as pulse pressure.

Age by itself was not a statistically significant factor, although there was a slight tendency toward increased arterial size with advancing age. No statistically significant difference in arterial size could be found between the older angiographic and the more recent examinations with serial filming. Neither was the angle of the central beam for filming in frontal views of any definite statistical significance. The trend was for measurements C, M, and to be a little greater in half-axial than in anteroposterior views. Arterial size taken as a sum of M, C and C₅ was significantly dependent on sex (T value of 5.46) even when the effect of skull size was eliminated by giving this a constant value. The finding of cerebral arteries smaller in females than males was reflected more in measurement C₅ than C and M, both with regard to the difference (Table 2) and its significance, as demonstrated with T values, of 5.92, 2.38 and 2.65, respectively.

Arterial size (sum of M, C, and C₅) was not significantly related to maximum skull length from the inner table of the frontal bone to the inner table of the occipital bone when the maximum external cranial width in the parietal area was kept constant. This latter measurement, however, showed a correlation with increasing size of the cerebral arteries (T value of 2.72) when the skull length was held constant. The external biparietal diameter was also individually correlated in a positive manner with measurements C₅ (T value of 1.58), C (T value of 1.90), and M (T value of 2.36).

The combined effect of sex and skull width on M, C₁, C₅, and the sum of these variables, are indicated by the formulas in Table 3 where W' is the external biparietal diameter measured in centimeters.

Cases with a history of migraine had smaller arteries (T value of 4.05 for the sum of M, C, and C₅) than the total group. Although nine of ten cases with migraine were females, the correlation between migraine and small arterial size could not be accounted for entirely on the basis of sex and skull size. A less striking, opposite relationship was noted for the other types of headache and trigeminal neuralgia, in which the arterial size statistically was larger than for either the entire material of 156 cases or the epilepsy group (T value of 2.56).

When M, C, and C₅ were studied individually, C and M bore a less marked relationship to the clinical history of migraine, other headache, and trigeminal neuralgia, in that order of decreasing dependence. Compared to the total group, C₅ tended to be greater in the four cases of trigeminal neuralgia (T value of +1.63), greater in other types of headache (T value of +2.64), and smaller in migraine (T value of -2.95).

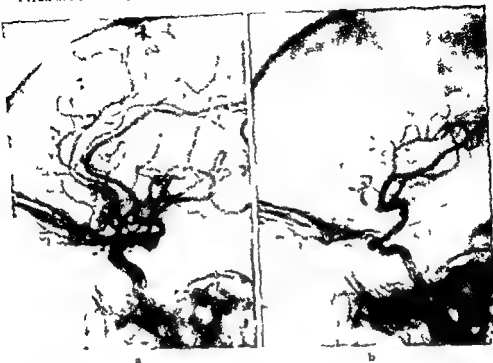


Fig 3 Normal case a) Lateral projection in left carotid angiography The internal carotid artery is unusually wide and supplies both pericallosal arteries b) The right internal carotid artery supplies only the middle cerebral artery and is narrow

Inspection of the data for cases with migraine revealed that eight of the ten had a C_1 size smaller than the expected mean with regard to sex and skull width. Three of these eight cases had a C_1 s of particularly small size.

With a T value of -2.06 the cases in which encephalography had been performed had slightly smaller cerebral arteries (0.49 mm difference for the sum of M_1 , C_1 , and C_2) than those without such examinations.

Discussion

Radiologic examinations associated with significant discomfort and possibly with morbidity, are rarely performed in clinically 'normal' cases. For this reason, it is difficult to collect a large series of carotid angiographies of normal individuals. The present material of carotid angiographies represents a highly select group both from the clinical and the radiologic aspects. The mean age was 33 years, which reflects clinical selection. Radiologic selection also eliminated

many cases in the older age groups on the basis of even minor cerebral atherosclerosis, ectasia of the cerebral arteries and cerebral atrophy

One might question whether the present results would have been different if carotid angiographies of cases presenting radiologic evidence of ectatic and atherosclerotic cerebral arteries had been included. A check investigation of part of the material has been made in order to judge the effects of such selectivity. Of 263 carotid angiographies coded as normal in the Department of Neuro-radiology, Karolinska sjukhuset, only thirteen met the criteria for 'normal'. During the same period, there were 34 carotid angiographies coded as only ectasia and 8 as only atherosclerosis, thirty-four of these forty-two cases would have been excluded on the basis of various neurologic abnormalities and six of the remaining seven cases would have been eliminated due to other abnormal states diagnosed by additional roentgenographic examinations. That leaves one case with ectasia as the only objective evidence of clinically and radiologically presumed abnormality. It seems probable that there had been proportionately fewer cases diagnosed as ectasia of the cerebral arteries at Serafimerlasarettet.

It thus seems unlikely that inclusion of carotid angiographies with ectatic and atherosclerotic arteries would have significantly altered the values that have been cited as normal diameters for the cerebral arteries. However, it might have slightly increased the average age of the patients and influenced the correlation of arterial size with age and blood pressure.

Although the difference was minor, the cerebral artery size was smaller (a difference of 0.5 mm for the sum of M, C and C₅), with statistical significance, in the 133 cases investigated with encephalography than in those without such examinations. The selection of cases was probably responsible. Cases in which also encephalography was normal may be more 'normal'.

The writers are well aware of the fact that the contrast media used for carotid angiography produce dilatation of the cerebral veins (GREITZ 1966) and probably also of the arteries (HUBER & HANDA 1967). However, such arterial dilatation apparently develops after maximum filling of the carotid siphon and could not significantly have affected our measurements.

Cases with subintimal injection of contrast medium were not included in the study because this procedure often leads to reduced blood flow in the carotid artery and the artery might be narrowed. Nor were examinations with intracranial arterial spasm, which had been coded as pathologic, included in the study. Cases with marked spasm of the internal carotid artery in the neck had sometimes been coded as normal but were also excluded. Some spasm may be associated with every carotid puncture but always stops short of the carotid canal, this can be accurately determined since the walls of the carotid canal are easily seen when the artery is filled.

The size of the error of measurement may be appreciable in measurements from an individual examination as compared with the small variations reported as dependent on sex and skull width. However, this does not alter the statistical significance of findings based on a large number of examinations. An error of measurement must also be differentiated from the standard deviation cited for each mean arterial measurement. The latter is mainly a function of anatomical variation or possibly pathologic change. The largest standard deviation was found for measurement A. It is well known that the first portion of the anterior cerebral artery may be small on one side and commensurately larger on the other side, it is reasonable to assume that such variation will influence the size of the internal carotid artery (Fig. 3). The writers made no systematic investigation of the relationship between the size of the internal carotid artery and variations in the circle of Willis.

Spasm of the intracranial arteries has been observed during an acute attack of migraine. The writers cannot completely rule out the possibility that the three patients with migraine, who had the narrowest arteries, may have been examined by carotid angiography during at least the initial stage of an acute attack. On the other hand, the present findings also raise the possibility that patients with migraine may have had cerebral arteries subnormal in size even between acute attacks.

No firm conclusions can be reached regarding trigeminal neuralgia, since there were only four such patients in the present material. The trend towards an increase in the C_5 measurement in these patients probably warrants further investigation.

An increased size in the C_5 measurement in the group of other types of headache suggests another etiologic mechanism than for migraine.

Conclusions

The size of the internal carotid and middle cerebral arteries is somewhat dependent on sex and skull width. In this study of strictly selected, normal carotid angiographies, no definite correlation of statistical significance between the size of these cerebral arteries and the variables site of injection, side of injection, age of patient, blood pressure, and electro-encephalographic findings was evident. As compared to the epilepsy group of the entire material, the internal carotid artery in other types of headache as

A series of test films for calibrating purposes may on request be obtained from Professor T. Greitz, Karolinska sjukhuset 104 01 Stockholm 60 Sweden.

Acknowledgements

The statistical analysis was done by Mr Erik Leander, Lecturer in Statistics, University of Stockholm. The study was supported in part by a grant from the Research Council of the Swedish Life Offices. Most of the data for this investigation were collected in 1965 while one of the authors (TOG) was on an off campus assignment from the Department of Radiology, University of Michigan Medical Center, Ann Arbor, Michigan, U.S.A.

SUMMARY

The size of the internal carotid, the middle cerebral, and the anterior cerebral arteries was determined in 156 normal carotid angiographies selected by strict clinical and radiologic criteria. The data were analyzed statistically.

ZUSAMMENFASSUNG

Die Weite der Aa. carotis interna, cerebri media und cerebri anterior wurde in 156 normalen Karotisangiographien gemessen, die durch klinischen und radiologischen Kriterien ausgewählt wurden. Die Daten wurden statistisch analysiert.

RÉSUMÉ

Les auteurs ont mesuré sur 156 angiographies carotidiennes normales, choisies sur des critères cliniques et radiologiques très stricts, le diamètre de l'artère carotide interne et des artères cérébrales moyenne et antérieure. Ils ont analysé statistiquement ces résultats en fonction de plusieurs variables.

REFERENCES

- DAVID M., DILENCE D., MORICE J. et PRADAT P. Migraine accompagnée. Etude angiographique. *Presse méd.* 74 (1966), 2604.
- DUKES H. T. and VIETH R. G. Cerebral arteriography during migraine prodrome and headache. *Neurology* 14 (1964), 636.
- GREITZ T. Dilatation of cerebral veins during cerebral angiography with water soluble contrast media. *Acta radiol. Diagnosis* 4 (1966), 625.
- HUBER P. and HANDA J. J. Effect of contrast material, hypercapnia, hyperventilation, hypertonic glucose and papaverine on the diameter of the cerebral arteries. Angiographic determination in man. *Invest. Radiol.* 2 (1967), 17.
- LINDGREN E. The technique of direct (percutaneous) cerebral angiography. *Brit. J. Radiol.* 20 (1947), 236.
- WOLLSCHLAEGER P. B. and WOLLSCHLAEGER G. Anterior cerebral/internal carotid artery and middle cerebral/internal carotid artery ratios. *Acta radiol. Diagnosis* 5 (1966), 615.

SKULL SIZE AND VENTRICULAR DILATATION IN SUBDURAL HYGROMA IN INFANTS

by

S CROQVIST and H O ERSING

A new index for determination of the size of the neurocranium has recently been applied in a series of cases of various neurologic disorders (CROQVIST 1968). The skull was found to be enlarged in 15 out of 20 children with subdural hygroma. Since in early age the size and the form of the neurocranium is dependent upon the intracranial content, it was at first believed that the hygroma itself, being a space occupying process, was the direct cause of this enlargement. We have, however, noted that disproportion almost always existed between the degree of cranial enlargement and the depth and extent of the hygroma, the size of the neurocranium far exceeded its normal upper limit even if the hygroma was only a few millimeters deep. This observation called for another explanation as to the cause of the increase in cranial size in these cases and prompted a review of our series of cases examined roentgenologically with the diagnosis of subdural hygroma.

Methods Cases of probable subdural hygroma at our hospital are always referred for roentgenologic examination. This consists of conventional skull films and encephalography, which, in our opinion, is the only special procedure needed for a diagnosis and only exceptionally has to be supplemented with angiography.

Submitted for publication 21 March 1969

Acknowledgements

The statistical analysis was done by Mr Erik Leander, Lecturer in Statistics, University of Stockholm. The study was supported in part by a grant from the Research Council of the Swedish Life Offices. Most of the data for this investigation were collected in 1963 while one of the authors (TOG) was on an off campus assignment from the Department of Radiology, University of Michigan Medical Center, Ann Arbor, Michigan, U.S.A.

SUMMARY

The size of the internal carotid, the middle cerebral and the anterior cerebral arteries was determined in 156 normal carotid angiographies selected by strict clinical and radiologic criteria. The data were analyzed statistically.

ZUSAMMENFASSUNG

Die Weite der Aa. carotis interna, cerebri media und cerebri anterior wurde in 156 normalen Karotisangiographien gemessen, die durch klinischen und radiologischen Kriterien ausgewählt wurden. Die Daten wurden statistisch analysiert.

RÉSUMÉ

Les auteurs ont mesuré sur 156 angiographies carotidiennes normales choisies sur des critères cliniques et radiologiques très stricts, le diamètre de l'artère carotide interne et des artères cérébrales moyenne et antérieure. Ils ont analysé statistiquement ces résultats en fonction de plusieurs variables.

REFERENCES

- DAVID M., DILENCO D., MORICE J. et PRADAT P.: Migraine accompagnée. Étude angiographique. *Presse méd.* 74 (1966) 2604.
- DUKES H. T. and VIETH R. G.: Cerebral arteriography during migraine prodrome and headache. *Neurology* 14 (1964) 636.
- GREITZ T.: Dilatation of cerebral veins during cerebral angiography with water soluble contrast media. *Acta radiol. Diagnosis* 4 (1966) 625.
- HUBER P. and HANDA J. J.: Effect of contrast material, hypercapnia, hyperventilation, hypertonic glucose and papaverine on the diameter of the cerebral arteries. angiographic determination in man. *Invest. Radiol.* 2 (1967) 17.
- LINDGREN E.: The technique of direct (percutaneous) cerebral angiography. *Brit. J. Radiol.* 20 (1947) 236.
- WOLLSCHLAEGER P. B. and WOLLSCHLAEGER G.: Anterior cerebral/internal carotid artery and middle cerebral/internal carotid artery ratios. *Acta radiol. Diagnosis* 5 (1966) 615.

Results

Roentgenologic examination of the skull before operation disclosed enlargement of the neurocranium in twenty eight of the thirty nine cases. The diagnosis was based upon the cranial index, which in these twenty eight cases proved to exceed the upper normal limit of 56.0. Encephalography or angiography indicated unilateral hygroma in fourteen and bilateral in twenty three cases. The roentgenologic diagnosis was uncertain in two cases. Ventricular dilatation with an index exceeding 0.30 was present in thirty two of the cases.

The ventricles were symmetric, i.e. there was no significant difference in the sizes of the right and left ventricles, in eighteen cases, with an operation finding of bilateral hygroma in ten and unilateral hygroma in eight cases. Asymmetry with a difference between the Evans' index on the two sides equal to or exceeding 0.02 was noted in twenty one cases. Ten of these had bilateral hygroma at operation, a unilateral hygroma being present in the remaining eleven cases. The widest ventricle lay on the side of the hygroma in six and on the contralateral side in five of these eleven cases.

The relation between the size of the neurocranium and the degree of ventricular dilation was further investigated. The Evans' index indicated ventricular dilatation in twenty five of the twenty eight cases with an enlarged neurocranium (C index > 56.0). Dilated ventricles were also present in seven of the eleven cases with a normal cranial size (C-index < 56.0).

None of the six postoperative encephalographic studies was undertaken merely to control the result of the operation; the indication for the investigation was either persistence of symptoms or development of new neurologic signs. Encephalography was completely normal in three cases. One case had normal ventricles but no passage of gas over the convexity on the operated side was seen. Marked atrophy, both central and cortical, was noted on the operated side in the fifth case. Increased dilatation of the ventricles was present in the sixth case operated upon for unilateral hygroma; there were however no signs of any residues of the hygroma, the air over the the convexity being in close contact with the internal table of the skull. The gas reached the convexity of the brain from the interpeduncular cistern via the dilated ambient cistern with no air passing beyond the chiasmatic cistern, i.e. there were signs of basal arachnoiditis. The postoperative skull study indicated an increase in the cranial index as compared to that in the earlier investigation.

Discussion

Increase in the size of the neurocranium measured along the circumference of the skull as a sign of chronic subdural hygroma in children was established by

The size of the neurocranium is determined from these films by means of the cranial index developed by one of the present authors (CRONQVIST 1968). The index is based upon measurements made between the inner tables of the skull and include the greatest length (L), greatest width (W) and greatest height (H). The latter is the maximum perpendicular distance between a line drawn from the nasion to the posterior margin of the foramen magnum and the vault of the skull. In addition, the maximum distance between the inner margins of the two necks of the mandible is measured on the film obtained in a p projection (M). The cranial index (C-index) is then obtained from the formula

$$C = \frac{L + W + H}{M} \times 10$$
 The mean value of this index based upon normal skull films is $53.5 \pm 2 \times 1.21$. A value above 56.0 thus indicates a pathologic increase in size of the neurocranium.

The encephalographic changes characterizing a subdural hygroma are of two different kinds (ROBERTSON 1957). The hygroma is sometimes manifest because of an increased distance between the calvarium and the surface of the brain, i.e. the gas-filled sulci on the convexity (DYKE 1936). This finding is diagnostic. Sometimes, however, no gas passes to the convexity on the side of the hygroma (LINDGREN 1942), this is suggestive but does not permit of a definite diagnosis.

In this series, the size of the cranial ventricles was determined by the method of EVANS (1942). The maximum width of the anterior horns was taken as the greatest distance from the septum pellucidum to the most lateral border of the ventricle on each side in the a.p. films. In addition, the distance between the midline and the inner table of the skull was measured on both sides. The ventricular measurement and the skull measurement from each side were inter-related. The index thus obtained has, according to EVANS, a normal upper limit of 0.30, an index above this is thus to be considered as pathologic and indicates dilatation of the lateral ventricles. Measurements for the normal variation in the width of the anterior horns have been given by LODIN (1968). We have used these figures for calculating the difference in the Evans index on the two sides. A value equal to or above 0.02 was found to signify pathologic asymmetry.

Material. The present series consists of 39 cases, 27 boys and 12 girls of ages varying between one month and 19 months, with an average of 7 months. Encephalography with adequate air filling of the ventricular system had been made in all cases. Conventional roentgenography of the skull was carried out prior to operation, which verified the presence of hygroma, unilateral or bilateral, in all the thirty-nine cases. Postoperative encephalography was performed in six cases.

hygroma compressing the subarachnoid space, with impairment of the circulation of the spinal fluid and, as a consequence, its resorption. The other kind seems to be secondary to atrophy of the brain tissue also evident as cortical changes, i.e. widened sulci (cf. CRONQVIST 1968).

Since, as has been shown, ventricular dilatation seems to be reflected in the size of the head it was thought of interest to compare the skull size and the type of encephalographic changes characterized or suggesting the presence of a hygroma. It was found that the group with no air passing over the convexity had a larger cranial index than the second group with air-filled sulci. The cranial index of the two groups was 58.1 and 56.1, respectively. Although there is so far no statistical analysis, this observation would appear to favour the existence of two different types of ventricular dilatation in cases of subdural hygroma.

Two different methods of examination should be used for the further analyses of the mechanism of ventricular dilatation. One is a new isotope method of gamma cisternography (DiCHIRO) which permits studies of the pathways of the cerebrospinal fluid and of its resorption. There are reasons to believe that the procedure will afford valuable information even from the viewpoint of diagnosis. The other examination that should be carried out is postoperative encephalography. The aim of such a follow-up study would be to control the results of surgery as to passage of gas in the subarachnoid space or regression of the medial displacement of the surface of the brain registered prior to operation, and ventricular size.

The observations on the six postoperative encephalographies available in this series are not conclusive. The indications for the investigations were persistent symptoms or development of new neurologic signs. Thus, no examination was performed in cases with obvious regression of clinical signs. However, even in the present cases no further ventricular dilatation was present after operation, with the exception of one case with added basal arachnoiditis. It should be pointed out that results of such an encephalographic follow-up investigation as suggested may help in solving the disputed problems as to whether cases of hygroma should be actively treated or not.

SUMMARY

The present study is a retrospective analysis of 10 cases of subdural hygroma. The relationship between the skull size and the type of ventricular dilatation was investigated. A relationship between the two entities seems to exist. Possible explanations and further studies are suggested.

INGRAHAM & MATSON (1954), and was present in about 29 per cent of their cases. A higher figure was given by TRFUNDICHI *et coll.* (1956) who found the circumference of the head to be enlarged in fourteen of nineteen cases. These authors pointed out, however, that their cases were selected, most of them being admitted to hospital because of this special sign.

The cranial index used in the present study has previously proved to be a sensitive indicator of changes in the size of the skull. Enlargement of the head was present in no less than twenty-eight of the thirty-nine cases in the series. An increase in the size of the head thus seems to occur more frequently than suggested in earlier reports. It was further observed that ventricular dilatation was present in the majority of the cases, i.e. in thirty-two. It occurred in twenty-five of the twenty-eight cases of enlargement of the head. This suggests that ventricular dilatation may be the cause of the increase in size.

The reason for the dilatation of the ventricles is so far unknown. There seems however to be some justification for imagining a mechanism similar to the one acting in cases of basal arachnoiditis, in which fibrous membranes, formed within the cisterns, cause a blockage of the circulation of the cerebrospinal fluid. The result is decreased resorption, secondary to which dilatation of the ventricles may develop. Impairment of the circulation of the spinal fluid may also possibly arise from a subdural hygroma causing compression of closely related parts of the subarachnoid space. The existence of such compression in the present series was indicated in the encephalograms by the absence of air in the subarachnoid space frequently noted on the side of the hygroma. This was observed in a group comprising twenty-four of our cases. In the other group, consisting of the remaining fifteen cases of our series, the hygroma was instead manifest as an increased distance between the inner table of the skull and the surface of the brain. Widened ventricles in these two groups were present in twenty-three and nine cases, respectively. The difference between the frequency of ventricular dilatation in the two groups favours the theory that compression of the subarachnoid space, with disturbance of the flow of the spinal fluid, actually existed in the first mentioned group. In the other group, the one in which the hygroma was indicated in the encephalogram by the increased distance between the calvarium and the convexity of the brain, the air had passed to the convexities where it lay in the sulci. These sulci often appeared wider than normal and the finding was then similar to that occurring in cortical atrophy. This type of atrophy in cases of subdural hygroma was noted by INGRAHAM & MATSON, who also pointed out that it was often combined with signs of central atrophy, i.e. ventricular dilatation.

The dilatation of the ventricles observed in this series may thus be divided into two kinds. One probably represents external hydrocephalus and is caused by the

hygroma compressing the subarachnoid space, with impairment of the circulation of the spinal fluid and, as a consequence, its resorption. The other kind seems to be secondary to atrophy of the brain tissue also evident as cortical changes, i.e. widened sulci (cf. CRONQVIST 1968).

Since, as has been shown, ventricular dilatation seems to be reflected in the size of the head it was thought of interest to compare the skull size and the type of encephalographic changes characterized or suggesting the presence of a hygroma. It was found that the group with no air passing over the convexity had a larger cranial index than the second group with air filled sulci. The cranial

of the mechanism of ventricular dilatation. One is a new isotope method of gamma cisternography (DICHIRO) which permits studies of the pathways of the cerebrospinal fluid and of its resorption. There are reasons to believe that the procedure will afford valuable information even from the viewpoint of diagnosis. The other examination that should be carried out is postoperative encephalography. The aim of such a follow up study would be to control the results of surgery as to passage of gas in the subarachnoid space or regression of the medial displacement of the surface of the brain registered prior to operation, and ventricular size.

The observations on the six postoperative encephalographies available in this series are not conclusive. The indications for the investigations were persistent symptoms or development of new neurologic signs. Thus, no examination was performed in cases with obvious regression of clinical signs. However, even in the present cases no further ventricular dilatation was present after operation, with the exception of one case with added basal arachnoiditis. It should be pointed out that results of such an encephalographic follow up investigation as suggested may help in solving the disputed problems as to whether cases of hygroma should be actively treated or not.

SUMMARY

Thirty nine cases of subdural hygroma have been investigated with roentgen examination of the skull and encephalography. An increase in the size of the head occurred in nearly all the cases. Ventricular dilatation was noted in twenty eight cases most of which also had enlargement of the neurocranium. A relationship between the two entities seems to exist. Possible explanations and further studies are suggested.

ZUSAMMENFASSUNG

Ein Material von neununddreissig Fällen von subduralem Hygrom wurde mittels gewöhnlichen Röntgenaufnahmen und mittels Enzephalographie untersucht. Vergrösserung des Schädels wurde in den meisten Fällen gesehen. Dilatation der Ventrikel war in achtundzwanzig Fällen vorhanden und in den meisten von diesen war auch der Schädel vergrössert. Diese zwei Erscheinungen durften sogar in Zusammenhang stehen. Erklärungsgründe werden erlautert und weitere Untersuchungen vorgeschlagen.

RÉSUMÉ

Trente neuf cas d'hydrome sous dural ont été examinés par radiographies du crâne et encephalographie. Il y avait dans presque tous les cas une augmentation évidente du volume de la tête. Il y avait une dilatation ventriculaire dans 28 cas dont la plupart avaient aussi une augmentation de volume du crâne. Il semble donc y avoir une relation entre ces deux anomalies. Les auteurs étudient les explications possibles de ces faits et proposent la poursuite de ces recherches.

REFERENCES

- CRONQVIST E. Roentgenologic evaluation of cranial size in children. A new index. *Acta radiol. Diagnosis* 7 (1968), 97.
- DI CHIRO G., REAMES P. M. and MATTHEWS W. B. RISA ventriculography and RISA-cisternography. *Neurology (Minneapolis)* 14 (1964), 185.
- DYKE C. G. Pathognomonic encephalographic sign of subdural haematoma. *Bull. neurol. Inst. N. Y.* 5 (1936), 135.
- EVANS W. A. An encephalographic ratio for estimating the size of the cerebral ventricles. Further experiments with serial observations. *Amer. J. Dis. Child.* 64 (1942), 820.
- FREUNDLICH E., BELLER A. J. and BERMAN S. Subdural hematoma in infancy. *Amer. J. Dis. Child.* 91 (1956), 608.
- INGRAHAM F. D. and MATSON D. D. *Neurosurgery of infancy and childhood*. Charles C. Thomas, Springfield, Illinois 1954.
- LINDGREN E. Zur Röntgendiagnose des Subduralhamatoms. *Acta radiol.* 23 (1942), 368.
- LÖDIN H. Size and development of the cerebral ventricular system in childhood. *Acta radiol. Diagnosis* 7 (1968), 385.
- ROBERTSON E. G. *Pneumoencephalography*. Charles C. Thomas, Springfield, Illinois 1957.

NEUROTOXICITY OF ROENTGEN CONTRAST MEDIA

Study of the blood-brain barrier in the rabbit following
selective injection of contrast media into the internal carotid artery

by

P G JEPSSON and TORD OLIN

The toxicity of modern contrast media injected intravenously is low. When such media are administered intra arterially, however, toxicity is still a problem and this is especially true for the central nervous system. Damage to the blood brain barrier following injection into the common carotid artery has been used as a parameter of the neurotoxicity of contrast media. BROMAN & OLSSON (1948) developed this method in the rabbit trypan blue, which will not normally leak through the barrier being used as an indicator to demonstrate the lesions. Similar studies have been made in other species, for example the dog (WHITELEATHER & DESALSSURE 1956).

Indicators other than trypan blue have also been used, for example sodium fluorescein (SMITH *et coll* 1951), ^{131}I human serum albumin (EDSTROM 1961) and ^3P -orthophosphate (GONSETTE & ANDRE BALISAUX 1967). Another method of studying damage to the capillary endothelium of the brain has been *microscopy* following silver staining (McCONNELL & MERSEREAU 1964). When the blood brain barrier is damaged, contrast medium leaks out into the brain parenchyma.

This work was supported by a grant (No B69-23A-605-03) from the Swedish Medical Research Council. Submitted for publication 26 February 1969.

Table 1

The various contrast media used in the present study

Trade name	Generic name and components	mg I/ml solution
Urografin 60 %	Diatrizoate Na 8 % Megl 52 %	290
Urografin 76 %	Diatrizoate Na 10 % Megl 66 %	370
Meglumine diatrizoate 60 %	Diatrizoate Megl 60 %	283
Sodium Iopaque 60 %	Metrizoate Na 60 %	350
Isopaque cerebral	Metrizoate Megl 59.1 % Ca 1.13 %	280
Conray 300	Iothalamic Na 50 %	300
Meglumine Conray 60 %	Iothalamic Megl 60 %	282

and clonic seizure usually develops, this has been used as a method to estimate the neurotoxicity (OLIN & REDMAN 1967). EEG changes after intracarotid injection of contrast media have been studied by BLOOR *et coll* (1951) and LUNDERVOLD & ENCFST (1967). Damage to the spinal cord following an injection of contrast medium into the aorta has been interpreted histologically in long-term experiments (MARGOLIS *et coll* 1958).

TORNELL (1969) studied the frequency of pareses following contrast medium injection into the aorta, which was occluded distally. The cardiovascular response, hypotonia and bradycardia, following an internal carotid injection has been used as an index of neurotoxicity (TORNELL 1968). No investigation seems to have been performed in which blood-brain barrier and cardiovascular reactions have been studied simultaneously in the same experiment. The purpose of the present investigation was to compare the effects on the blood brain barrier and on the general circulation of some of the new contrast media now in use for cerebral angiography. It was also considered necessary to compare a standardized injection technique at a fixed flow rate with previous methods. Selective injection into the internal carotid artery of the rabbit was preferred in order to make the conditions more distinct. This meant that a possible anomalous origin of the occipital artery from the internal carotid artery had to be taken into account (JEFFSSON & OLIN 1960).

Material and Methods Ninety-four rabbits, 2 kg in weight, were used. The animals were anaesthetized with sodium pentobarbital (mebumlinatrium 6 %) given intravenously. Artificial respiration was usually not used. The left carotid artery was exposed and the external carotid artery ligated. The most proximal

Table 2

Results using Urografin 60%

Rabbit	Contrast me- dium vol ml	Body wt kg	Body temp at in- j °C	Inj time in sec	Appli- cation time in sec	Pulse/min		Blood pressure mm Hg			Dura- tion of fall in sec	Degree of injury
						Before	During	Before	Fall	Rise		
K 31	10.0	1.5	38.2	65.5	68.8	300	60	105	0	40	8	++
K 32	10.0	1.2	37.2	65.0	64.4	240	210	75	15	35	8	+
K 55	10.0	1.5	38.6	66.0	64.0	—	—	95	5	25	—	+++
K 24	5.0	2.5	38.4	33.0	32.4	330	330	125	5	40	3	+++
K 28	5.0	2.6	39.0	32.5	32.0	270	180	110	0	40	0	++
K 29	5.0	3.2	39.2	31.0	30.4	300	240	100	10	30	5	neg
K 23	2.5	1.9	37.0	16.0	17.2	240	240	120	5	15	7	neg
K 26	2.5	1.5	38.6	18.5	19.6	270	270	100	8	17	8	neg
K 27	2.5	2.5	39.0	16.0	16.4	300	300	115	18	45	3	++

part of the internal carotid artery was inspected for an anomalously arising occipital artery, which was ligated when present. The common carotid artery was ligated caudally and then cannulated with a polythene catheter with an inner diameter of 1.15 mm (PE 160, Clay Adams, New York, USA). A burr-hole was made in the parietal region of the skull on the left side. The femoral vein and artery were cannulated with polythene catheters (PE 160), the vein being connected to a saline container and the artery to an electromanometer (Elema Schonander) for measurement of the blood pressure and pulse rate. The catheter in the carotid artery was connected to a 10 ml syringe, which was placed in an infusion machine (CLEMENTZ & OLIN 1961). The flow rate of the injection that expelled the blood in the pial vessels during the whole injection time was determined in pilot experiments to be about 0.16 ml/s, and this speed of injection was applied throughout the subsequent investigation. The time during which the pial blood vessels were rinsed of blood will be referred to as the application time. In contrast to previous authors, such as BROMAN & OLSSON (1956) and

whole time d

the length of the injection. The application was checked by inspection through the burr hole in the skull. The duration of the injection, the application time and the blood pressure and pulse rate were recorded on a polygraph (Mingograph 24, Elema Schonander). After the injection of the contrast medium, 100 ml of trypan blue 0.5% at room temperature were infused into the femoral vein

Table 1

The various contrast media used in the present study

Trade name	Generic name and components	mg I/ml solution
Urografin 60 %	Diatrizoate Na 8 % Megl 52 %	290
Urografin 76 %	Diatrizoate Na 10 % Megl 66 %	370
Meglumine diatrizoate 60 %	Diatrizoate Megl 60 %	283
Sodium Iopaque 60 %	Metrizoate Na 60 %	350
Iopaque cerebral	Metrizoate Megl 59.1 % Ca 1.13 %	280
Conray 300	Iothalamate Na 50 %	300
Meglumine Conray 60 %	Iothalamate Megl 60 %	282

and clonic seizure usually develops, this has been used as a method to estimate the neurotoxicity (OLIN & REDMAN 1967). EEG changes after intracarotid injection of contrast media have been studied by BLOOR *et coll* (1951) and LUNDERVOLD & ENGSET (1967). Damage to the spinal cord following an injection of contrast medium into the aorta has been interpreted histologically in long-term experiments (MARGOLIS *et coll* 1958).

TORNELL (1969) studied the frequency of pareses following contrast medium injection into the aorta, which was occluded distally. The cardiovascular response, hypotonia and bradycardia, following an internal carotid injection has been used as an index of neurotoxicity (TORNELL 1968). No investigation seems to have been performed in which blood-brain barrier and cardiovascular reactions have been studied simultaneously in the same experiment. The purpose of the present investigation was to compare the effects on the blood-brain barrier and on the general circulation of some of the new contrast media now in use for cerebral angiography. It was also considered necessary to compare a standardized injection technique at a fixed flow rate with previous methods. Selective injection into the internal carotid artery of the rabbit was preferred in order to make the conditions more distinct. This meant that a possible anomalous origin of the occipital artery from the internal carotid artery had to be taken into account (JEFFSSON & OLIN 1960).

Material and Methods Ninety-four rabbits, 2 kg in weight, were used. The animals were anaesthetized with sodium pentobarbital (mebumalnatruium 0.5%) given intravenously, artificial respiration was usually not used. The left carotid artery was exposed and the external carotid artery ligated. The most proximal

Table 2
Results using Urografin 60 %

Rabbit	Contrast medium vol ml	Body wt kg	Body temp at inj °C	Inj time in sec	Applic. time in sec	Pulse/min		Blood pressure mm Hg			Duration of fall in sec	Degree of injury
						Before	During	Before	Fall	Rise		
K 31	100	1.5	38.2	65.5	68.8	300	60	105	0	40	0	+(+)
K 32	100	1.2	37.2	65.0	64.4	240	210	75	15	35	8	+
K 55	100	1.3	38.6	66.0	64.0	—	—	95	5	25	—	+++
K 24	50	2.5	38.4	33.0	32.4	330	330	125	5	40	3	+++
K 28	50	2.6	39.0	32.5	32.0	270	180	110	0	40	0	++
K 29	50	3.2	39.2	31.0	30.4	300	240	100	10	30	5	neg
K 25	2.5	1.9	37.0	16.0	17.2	240	240	120	5	15	7	neg
K 26	2.5	1.5	38.6	18.5	19.6	270	270	100	0	17	0	neg
K 27	2.5	2.5	39.0	16.0	16.4	300	300	115	18	45	3	++

part of the internal carotid artery was inspected for an anomalously arising occipital artery, which was ligated when present. The common carotid artery was ligated caudally and then cannulated with a polythene catheter with an inner diameter of 1.15 mm (PE 160, Clay Adams, New York, USA). A burr-hole was made in the parietal region of the skull on the left side. The femoral vein and artery were cannulated with polythene catheters (PE 160), the vein being connected to a saline container and the artery to an electromanometer (Elema Schonander) for measurement of the blood pressure and pulse rate. The catheter in the carotid artery was connected to a 10 ml syringe, which was placed in an infusion machine (CLEMENTZ & OLIN 1961). The flow rate of the injection that expelled the blood in the pial vessels during the whole injection time was determined in pilot experiments to be about 0.16 ml/s and this speed of injection was applied throughout the subsequent investigation. The time during which the pial blood vessels were rinsed of blood will be referred to as the application time. In contrast to previous authors, such as BROMAN & OLSSON (1956) and JERSSON (1962), the application time in the present work means the whole time during which the blood in the pial vessels was expelled, regardless of the length of the injection. The application was checked by inspection through the burr hole in the skull. The duration of the injection, the application time and the blood pressure and pulse rate were recorded on a polygraph (Mingograph 24, Elema Schonander). After the injection of the contrast medium, 100 ml of trypan blue 0.5 % at room temperature were infused into the femoral vein.

Table 3
Results using Urografin 76 %

Rabbit	Contrast media volume ml	Body wt kg	Body temp at inj °C	Inject time in sec	Appl. cation time in sec	Pulse/min		Blood pressure mm Hg			Duration of fall in sec	Degree of injury
						Before	During	Before	Fall	Rise		
K5	10.0	2.8	—	61.0	61.2	215	65	105	10	5	1	+++
K56	10.0	2.4	39.0	63.5	66.0	240	90	115	5	10	3	+
K57*	10.0	2.0	38.0	—	—	—	—	—	—	—	—	+++
K6	5.0	1.5	—	31.0	34.0	120	115	100	0	0	0	++
K59	5.0	2.3	39.2	33.0	31.0	210	90	105	35	60	6	++
K60	5.0	2.7	38.3	33.0	30.5	270	300	115	20	10	6	+++
K7	2.5	2.3	—	16.0	13.0	275	180	130	0	60	0	+++
K62	2.5	1.5	38.2	17.0	17.0	300	240	115	0	60	0	++
K63	2.5	2.2	39.2	17.0	17.0	270	240	65	0	80	0	+++
K8	1.25	2.1	—	7.5	8.2	205	210	120	2	47	0	+
K11	1.25	1.9	36.4	8.0	8.4	185	210	120	0	10	0	(+)
K117	1.25	2.5	39.0	8.0	9.0	210	210	85	10	5	3	(+)

*The left occipital artery arose from the internal carotid artery.

After an infusion time of about 15 minutes, the animal was killed and the cerebral vessels rinsed with 300 ml saline solution 0.9 % through a catheter inserted cranially into the aorta. The brain was fixed in situ with 200 ml formalin 10 % introduced via the catheter in the aorta. The degree of injury to the brains was rated and the latter were then examined microscopically as described by JIPSSON (1962). The contrast media used are listed in Table 1, they were at room temperature (20—24 °C) when injected. The rectal temperature was recorded with a thermometer inserted 9 cm above the anus.

The dose was varied from 10.0 ml downwards in order to evaluate the toxicity of different contrast media. The dose was halved to 5.0, 2.5, 1.25 and 0.65 ml until no or only very slight damage to the blood-brain barrier occurred. Three animals were used at each dose level. Some experiments were used as controls to ensure that the technique used did not cause any lesion of the blood-brain barrier. The anatomy of the internal carotid artery on the injected side was checked by post mortem angiography with a barium suspension.

Results

Urografin 60 % (Table 2). Nine animals were used, equally divided between doses of 10.0, 5.0 and 2.5 ml. No animal had a maximal lesion. With the lowest

Table 4

Results using meglumine diatrizoate 60 %

Rabbit	Con- trast me- dium vol ml	Body wt kg	Body temp at inj °C	Inject time in sec	Apph- cation time in sec	Pulse/min		Blood pressure mm Hg			Dura- tion of fall in sec	Degree of injury
						Before	During	Before	Fall	Rise		
K101	100	19	38.0	63.5	63.5	300	270	95	0	30	0	++
K115	100	22	38.0	63.5	68.0	240	240	85	0	0	0	+++
K116*	100	25	36.2	64.0	91.0	270	180	60	5	15	3	neg
K102	50	18	39.0	33.0	32.0	300	300	85	10	40	4	++
K112	50	34	38.4	33.0	33.0	300	300	145	20	45	4	++++
K114	50	24	38.7	33.0	33.0	240	180	50	0	30	0	+
K103	25	22	38.2	16.5	15.0	240	240	80	5	5	3	(+?)
K108	25	20	38.0	16.0	15.5	270	240	125	0	10	0	(+)
K109	25	20	38.0	16.5	16.5	270	240	110	35	10	9	(+)

* Injection on the right side. Left common carotid artery ligated

dose, no staining of the brain was observed in two of the three animals. The effect of the injection on the pulse rate was almost negligible. One animal, however, developed marked bradycardia with the 100 ml dose. The fall in blood pressure was also small and bore no relation of the amount of contrast medium injected. The rise in blood pressure was evident but apparently did not vary with the dose.

Urografin 76 % (Table 3). Fifteen animals were used, equally divided between doses of 100, 50, 25 and 12.5 ml. A small lesion in the blood brain barrier was present in the last group. Two of three animals in the 100 ml group had a maximal lesion of the brain. Rather marked bradycardia occurred with the two highest doses, the two smallest doses, however, produced only slight bradycardia. The fall in blood pressure was more obvious in the groups given 100 and 50 ml than in the other two groups. The rise in blood pressure did not seem to depend on the dose.

Meglumine diatrizoate 60 % (Table 4). Nine animals were used, equally divided between doses of 100, 50 and 25 ml. Damage to the blood brain barrier was slight with the lowest dose. One animal had a maximal lesion which occurred with a dose of 5 ml. The application time in one of the animals that received an injection of 100 ml of contrast medium was one third longer than

Table 5
Results using Sodium Isopaque 60 %

Rabbit	Con- trast me- dium vol ml	Body wt kg	Body temp at inj °C	Inject time in sec	Appli- cation time in sec	Pulse/min		Blood pressure mm Hg			Dura- tion of fall in sec	Degree of injury
						Before	During	Before	Fall	Rise		
K43	10.0	1.5	38.0	67.0	67.2	300	120	95	10	60	3	++++
K73	10.0	2.5	39.4	65.0	68.0	300	60	130	30	45	4	++++
K44	5.0	1.4	38.0	34.5	35.2	315	165	95	5	50	2	++
K75	5.0	2.5	39.2	33.0	34.5	270	85	110	20	65	10	++++
K77	5.0	2.1	38.8	32.5	32.5	240	150	100	0	60	0	++++
K47	2.5	1.6	37.4	16.5	18.2	—	—	—	—	—	—	+++
K78	2.5	2.4	38.0	16.5	15.5	270	270	95	5	65	3	+
K79	2.5	1.4	38.2	17.0	17.0	300	90	95	5	60	2	++
K49	1.25	1.6	37.8	7.5	9.8	205	170	95	15	30	7	++(+)
K50	1.25	1.6	37.2	7.5	8.6	275	240	115	5	40	4	++(+)
K80	1.25	1.4	38.2	8.0	10.5	270	240	60	5	30	2	(+)
K52	0.65	1.5	37.0	4.0	4.8	300	270	115	0	15	0	(+?)
K53	0.65	2.0	37.2	4.5	8.0	240	210	130	25	105	4	(+?)
K54	0.65	1.7	37.0	4.5	7.0	300	270	125	15	25	3	+++

usual. This was probably due to the fact that both common carotid arteries were ligated. As the expulsion of blood in the pial vessel was not obtained on injection into the left carotid artery an injection was performed on the right side. The pulse rate was not affected by the injection of contrast medium. The fall in blood pressure was usually small or absent, any rise was moderate and not correlated to the dose.

Sodium Isopaque 60 % (Table 5). Two animals were injected with 10.0 ml and three animals were each given 5.0, 2.5, 1.25 and 0.65 ml. Damage to the blood-brain barrier was slight on injection of 0.65 ml. Four animals had maximal lesions with doses of 10.0 and 5.0 ml. The fall in pulse rate was marked in the two highest dose groups, the bradycardic response decreased with the dose. The fall in blood pressure was less severe and was not related to the dose, the rise in blood pressure seemed to increase with the higher doses.

Isopaque Cerebral 60 % (Table 6). Nine animals were injected, equally divided between doses of 10.0, 5.0 and 2.5 ml. No animal developed a maximal lesion. Damage to the barrier was slight in the 2.5 ml group. The effect on the

Table 6
Results using Isopaque Cerebral 60 %

Rabbit	Con- trast me- dium vol ml	Body wt kg	Body temp at inj °C	Inject time in sec	Appli- cation time in sec	Pulse/min		Blood pressure mm Hg			Dura- tion of fall in sec	Degree of injury
						Before	During	mm				
								Before	Fall	Rise		
K14	100	2.0	38.2	64.0	63.6	270	270	107	13	20	6	+++
K64	100	3.7	38.8	65.0	65.0	270	270	85	5	50	3	(+)
K65	100	2.1	38.5	65.0	64.5	270	240	120	0	0	8	+
K16*	50	3.1	37.4	32.0	30.4	250	220	110	13	5	8	+
K22	50	1.8	38.0	32.0	32.0	250	220	180	10	25	5	(+)
K23	50	3.2	38.0	32.0	32.0	300	280	125	0	30	8	+(+)
K17*	25	1.7	39.0	15.5	14.8	295	265	110	15	20	2	(+)
K19	25	2.2	39.0	16.5	16.2	260	235	120	18	38	5	(+?)
K21	25	2.2	39.2	16.0	16.0	275	270	115	25	15	3	(+)

* An anomalous occipital artery was ligated before the injection

pulse rate was slight. A definite fall in blood pressure usually occurred but did not seem to be related to the amount of medium injected. The rise in blood pressure was also definite although not related to the dose.

Conray 300 (Table 7) Twelve rabbits were divided equally between doses of 100, 50, 25 and 125 ml. Two animals had a maximal lesion of the blood brain barrier with doses of 100 and 50, respectively. At the 125 ml dose, two of three animals developed no lesion. A rather severe fall in pulse rate occurred with the higher doses. The fall in blood pressure was small and occurred only in some of the animals belonging to the highest dose groups. The rise in blood pressure was marked and especially so with the higher doses.

Meglumine Conray 60 % (Table 8) Two rabbits were given 100 ml into the internal carotid artery, and three animals were each given 50, 25 and 125 ml. One animal developed a maximal lesion of the blood brain barrier with the highest dose. The smallest dose produced no effect upon the barrier. The bradycardic response was virtually absent. A fall in blood pressure was the rule but apparently was not dependent on the dose, the rise in blood pressure was obvious and seemed to increase with the dose.

Results common to the different series The expulsion of the blood from the pial vessels was complete during the intracarotid injection in the experiments

Table 7
Results using Conray 300

Rabbit	Con- trast me- dium vol ml	Body wt kg	Body temp at inj °C	Inj time in sec	Appli- cation time in sec	Pulse/min		Blood pressure mm Hg			Dura- tion of fall in sec	Degree of injury
						Before	During	Before	Fall	Rise		
K33	100	1.4	37.8	63.0	63.6	—	—	80	0	20	0	++(+)
K66	100	2.1	39.0	64.5	64.5	240	75	55	5	75	6	++(+)
K67	100	1.9	39.0	63.5	64.5	300	120	115	0	65	0	++++
K34	50	1.4	37.3	32.5	33.6	300	90	115	10	35	2	++(+)
K68	50	2.2	38.4	33.0	33.6	300	240	105	20	55	5	++(+)
K71	50	2.3	38.0	32.5	33.0	270	75	95	0	50	0	++++
K35	2.5	1.7	37.0	16.5	16.8	270	240	80	—	30	—	++
K41	2.5	2.4	38.2	17.0	16.0	—	—	—	—	—	—	+++
K42	2.5	1.6	38.0	17.0	16.4	240	210	105	0	30	0	++
K36	1.25	1.4	37.0	7.5	8.0	270	240	105	0	45	0	neg
K39	1.25	1.7	38.2	8.5	8.2	210	210	60	0	10	0	neg
K40	1.25	1.7	37.0	9.0	8.0	240	210	70	0	55	0	++

Table 8
Results using Meglumine Conray 60 %

Rabbit	Con- trast me- dium vol ml	Body wt kg	Body temp at inj °C	Inj time in sec	Appli- cation time in sec	Pulse/min		Blood pressure mm Hg			Dura- tion of fall in sec	Degree of injury
						Before	During	Before	Fall	Rise		
K81	100	1.6	38.2	64.0	64.0	—	—	—	0	0	0	+++
K100	100	2.8	39.8	63.5	63.0	270	300	65	5	50	3	+++
K82	50	1.8	39.0	33.0	32.0	270	240	95	15	35	5	+
K93	50	2.8	—	32.5	31.0	300	270	110	20	40	6	+++
K97	50	2.4	39.0	33.0	31.0	270	270	100	5	30	2	++
K83	2.5	2.9	38.2	—	16.5	270	270	55	0	65	0	(+)
K84	2.5	3.5	38.0	16.0	16.0	210	195	95	15	20	5	+
K85	2.5	3.5	39.0	17.5	19.0	240	240	—	0	0	0	++(+)
K86	1.25	1.5	38.0	8.5	9.5	225	225	55	0	0	0	neg
K90	1.25	3.0	38.2	9.0	9.0	270	270	90	30	0	10	neg
K91	1.25	2.4	39.0	8.5	7.0	330	300	115	0	0	0	neg

Table 9

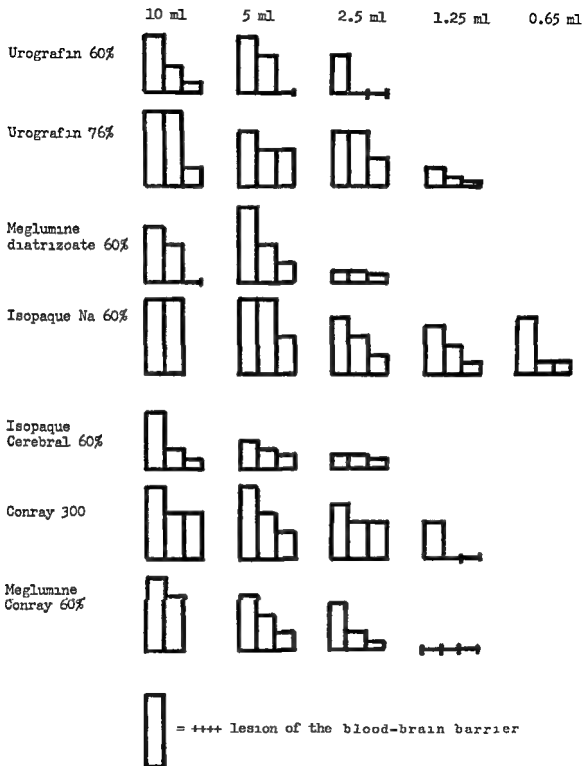
*Distribution of injury between different areas of vascular supply — The figures denote number of animals —
Nine brains were negative*

Experimental series	Total number of animals	Left internal carotid area most damaged or same as others	Left internal carotid area damaged		Left internal carotid area negative or slightly damaged	
			Right internal carotid area most damaged	Vertebral area most damaged	Right internal carotid area most damaged	Vertebral area most damaged
Urografin 60 %	9	4		2		
Urografin 76 %	12	9	1	2		
Meglumine diatrizoate 60 %	9	6			1	1
Sodium Isopaque 60 %	14	7		1	1	5
Isopaque Cerebral	9	6				3
Conray 300	12	3	2		3	2
Meglumine Conray 60 %	11	6	1			1
Total	76	41	4	5	5	12
						26

presented above. In 18 animals, the expulsion of the blood was not complete, i.e. the blood returned during the injection, or the expulsion was intermittent or partial. In ten of these eighteen animals the occipital artery arose anomalously from the internal carotid artery on the injected side. In one of the animals an occipital artery from the internal carotid artery was located before injection and ligated but in spite of this the expulsion of blood was incomplete. In one animal the internal carotid artery was ligated by mistake. In four animals no explanation was found for the incomplete expulsion of the blood from the pial vessels. These eighteen animals are not included in the tables. *Complete expulsion from the pial vessels occurred in seven animals with an anomalous occipital artery. One of them is included in the present series as it had a maximal lesion of the blood-brain barrier. The other six animals are excluded.*

Both the injection time and the application time were proportional to the amount of contrast medium injected.

The lesion of the barrier was usually most severe in the area of the internal



Survey of the degree of injury to the blood brain barrier in the different experimental series

carotid artery into which the injection was made, i.e. the left side (Table 9). However, in nine animals the contralateral carotid area was the most damaged. In five of these nine animals the left internal carotid area was affected only slightly or not at all. The area of the vertebral artery was the most damaged in seventeen animals, in twelve of these the left internal carotid area was only slightly damaged.

The lesion was usually uniform or patchy blue in colour. The brain appeared red to the naked eye in the cases with stasis. Blue staining of the walls of the vessels and diffuse staining of the parenchyma were observed at microscopy. Staining of the nucleus of parenchymal cells was sometimes present. Staining of the endothelial cell nuclei was virtually absent. The vessels were packed with red blood corpuscles in the cases with stasis.

Comparison of the series The effect of the roentgen contrast media on the blood brain barrier is illustrated in the accompanying figure. Urografin 60 %_{v/v}, Isopaque Cerebral and meglumine diatrizoate 60 %_{v/v} produced slight or no lesions at the 2.5 ml dose. These three contrast media appear to have the lowest toxicity among those tested. We consider however that the data do not selectively favour any of these three contrast media above the others. The figure also indicates that Urografin 76 %_{v/v}, Conray 300 and Meglumine Conray reach the 'non toxic' level at a dose of 1.25 ml. Isopaque 60 %_{v/v} could still produce a slight lesion in a dose of about 0.65 ml and was thus the most toxic of the seven different contrast media tested.

The cardiovascular reactions were most severe with roentgen contrast media containing sodium. Bradycardia appeared particularly at high doses of these contrast media. The fall in blood pressure was not dependent on the dose, with the exception of Urografin 76 %_{v/v}. The rise in blood pressure was most marked with high doses of Sodium Isopaque, Conray 300 and Conray Meglumine. The rise in blood pressure occurred more at random with injections of Urografin 76 %_{v/v} and Isopaque Cerebral.

Table 9 indicates that Sodium Isopaque 60 %_{v/v} and Conray 300 are those contrast media that contribute most to a paradoxical location of a lesion of the blood brain barrier.

The material was grouped according to the degree of the injury to the blood brain barrier. The four plus group contained most of the cases of marked bradycardia. The negative group produced the smallest response. The other cardiovascular parameters presented no tendency to be related to the degree of lesion. Only those contrast media that contained meglumine were investigated in the same way. The heart rate fell with decreasing dose. The blood pressure reactions were not related to the degree of lesion of the barrier.

Discussion

The technique used in the present investigation was preferred for several reasons. The rabbit has a better defined anatomy of the cerebral vessels than the animals used in similar experiments (JEPPISSON & OLIN 1960). By ligation of the internal carotid artery, and by taking an anomalous occipital artery into consideration, it is possible to ensure that the injected volume goes to the brain. Thus a more quantitative estimate of the amount of contrast medium necessary for provoking a lesion of the blood-brain barrier is possible.

Selective injection into the internal carotid artery cannot be made in the dog, the cat or the guinea-pig for anatomical reasons (see ASK-UPMARK 1935). Quantitative administration is therefore impossible in these animals but nevertheless they have been widely used. GONSETT & ANDRE-BALISAU (1967) used the guinea-pig, the dog was employed by HARRINGTON *et coll.* (1966), BASSETT *et coll.* (1953), KODAMA *et coll.* (1963), SMOLIK & NASH (1964) and FISCHER & LOKSTEIN (1961). CRAVER *et coll.* (1968) used cats in a study of the penetration of salts of diazotized compounds into the cerebral parenchyma. Their reasons for selecting cats was that the cerebral circulation of the cat was more like that of man than that of the dog. Injection has hitherto generally been made manually. STEINWALL (1958) preferred this method as it was possible to adjust the injection rate to the degree of expulsion of the blood from the pial vessels. In the present experiments an injection rate was chosen that gave complete expulsion from the vessels in pilot studies, when the above criteria of selective injection were fulfilled. By the use of an injection machine the injection rate could be standardized, the injection parameters are thus better defined on this point as well.

Expulsion of the blood from the pial vessels was sometimes not complete in spite of the standardization. This was explained in ten experiments by an anomalous occipital artery that was not discovered until the post-experimental roentgen examination of the internal carotid artery. It is a reasonable assumption that at a given injection rate an 'extra' vessel steals contrast medium from the vascular territory for which the dose is intended. Complete expulsion was however also obtained in experiments where an anomalous occipital artery was present. This might be explained by the dose being sufficient for the actual vascular territory in spite of this anomaly. It also happened that the expulsion of the blood was incomplete in spite of a normal vascular anatomy. No obvious explanation so far exists for this disturbing fact. However, it may be assumed that the vascular territory in these animals was too large for the actual injection rate. The effect on the blood-brain barrier of incomplete expulsion was obvious in some experiments as no lesion was produced, it may be argued that the lesion obtained would

have been more severe if the expulsion had been complete. It is also possible in the case of an anomalous occipital artery to argue that the whole dose had not entered the target area so that the lesion was less marked than if the whole dose had entered the cerebral vessels. It is for this reason that such experiments were excluded. Great variation in the degree of damage with the same dose however still existed. It is clear that research workers who study the injury to the blood-brain barrier by intracarotid injection without observing the degree of expulsion from the vessels in the injected area work with an uncontrolled source of error.

The total volume of contrast solution that has to be given to produce barrier damage is quite small with selective injection into the internal carotid artery as compared with the huge amount necessary to obtain corresponding damage to the barrier with injection into the common carotid artery. With injection into the latter the large volume of hypertonic solution severely disturbs the general circulation and therefore the jugular veins have to be cut. Due to the small amount used at selective injection into the internal carotid artery, the recirculation of the contrast medium can be disregarded.

The application time was closely correlated to the injected volume and to the injection time in the present study. In earlier studies (JEPPSSON 1962), the volume injected as well as the injection time were found to be closely correlated to the application time. In the choice between suitable indicators to demonstrate damage to the blood brain barrier we selected trypan blue, this has been widely used for many years (BROMAN & OLSSON 1948, 1956, JEPPSSON 1962). RIHSA ¹³¹I human serum albumin, was compared with ⁵¹CrCl₃ by EDSTROM (1961). STEINWALL & KLATZO (1965) studied cold injuries and used Evans blue and fluorescein as indicators. BAKER (1956) stated that ³²P was a more sensitive agent than vital dyes. However, he came to this conclusion by comparing his own experiments with ³²P with similar experiments performed with vital dyes as reported in the literature. MOORE (1953) studied the effect on the barrier produced by the injection of Diodrast into the common carotid artery in the rabbit. He used either sodium fluorescein or trypan blue as an indicator of injury to the barrier. He failed however, to find any difference in sensitivity between the two test substances. GONSETTE & ANDRE BALLSAUX (1967) stated that radioactive isotopes were more sensitive than trypan blue in detecting small lesions of the blood brain barrier. WHITELEATHER & DESAUSSEURE (1956) expressed the opinion that clinical signs, such as epileptic seizures, were more sensitive than trypan blue. The appearance of a seizure is usually inhibited by deep anaesthesia. The narcosis had to be rather deep in the present experiments due to the dissection in the neck.

So far no conclusive report regarding any substance superior to trypan blue in detecting an experimental injury to the blood brain barrier seems to have

been published. Due to the above-mentioned reasons and as the trypan blue method is easy to handle, we have preferred this technique.

Cardiovascular reactions to injection of roentgen contrast media into the carotid artery have been studied by LINDGREN & TORNELL (1958). They measured the blood pressure and the pulse rate at injections of sodium acetrizate into the carotid artery in cats. Bradycardia and hypotension occurred. They considered the first phase of the blood pressure fall to be secondary to the bradycardia, which was effectuated via the vagal nerves, and the second phase of the hypotension to be due to diminished vasoconstrictor discharge. They judged both phases to be related by the direct action of the medium injected on the vasomotor centres in the brain. The cardiovascular responses to the injection of contrast media into the common carotid artery of the dog were studied by FISCHER & ECKSTEIN (1961) and FISCHER & CORNELL (1965). They found that the sodium salts of diatrizoate, iothalamate and metrizoate gave more reactions than the corresponding methylglucamine salts; among the sodium salts, the diatrizoates caused the smallest reactions. CORNELL & FISCHER (1967), using the same technique, reported that a mixture of sodium and methylglucamine calcium and magnesium metrizoate altered the arterial blood pressure and heart rate more than pure methylglucamine metrizoate. A corresponding investigation with sodium iothalamate produced similar results. Clinical studies during carotid angiography (GREITZ & TORNELL 1967, GREITZ, TELENUS & TORNELL 1967, TORNELL 1968, LUNDFRÖLD & ENGQVIST 1967) have indicated that bradycardia to some extent may be due to the sodium ion of the contrast medium.

Bradycardia was also especially marked with high doses of sodium salts in the present studies in rabbits. Hypotension, however, has no direct connection with the sodium, except with Urografin 76%. The hypertension which succeeds the hypotension always occurs with the sodium salts (Isopaque 60% and Conray 300) and Meglumine Conray. The cardiovascular reactions that we observed have thus been especially associated with the presence of sodium ions. The sodium salts examined also present the highest neurotoxicity as assessed by the blood brain barrier technique. Since the bradycardia with injections of meglumine salts had a negative correlation to the barrier lesion, and since the reactions of the blood pressure varied irrespective of the lesion, the cardiovascular reactions are not a measure of the neurotoxicity as judged by lesions of the barrier. It should be noted, however, that the common carotid artery was ligated proximally in the experiments. On the other hand, the rabbit has a well-developed circle of Willis, so that the blood will generally rinse away the contrast medium from the brain vessels as soon as the injection is completed. In accordance with this the application time and the injection time are of about the same duration. No obvious correlation between the neurotoxicity and the cardiovascular reaction was found.

in some other studies of the neurotoxicity with injection into the vertebral artery (OLIN & REDMAN 1967). No brain vessels were occluded in these previous examinations. It would appear that the cardiovascular reactions are essentially a measure of the sodium percentage of the contrast media and not necessarily a measure of the neurotoxicity. The lesions of the barrier with a paradoxical location occur at the highest frequency for roentgen contrast media containing a high percentage of sodium salt. These contrast media also produce the most severe cardiovascular reactions.

The present studies of the effect of some modern roentgen contrast media on the blood brain barrier are on the whole in accordance with similar studies made by other investigators. Thus, sodium salts have produced a more intense lesion of the barrier with a certain dose as compared with a corresponding amount of a meglumine salt in the same roentgen contrast medium (KODAMA *et coll.* 1963, SALVESEN *et coll.* 1967b, GONSETTE & ANDRE-BALISAUX 1967). HARRINGTON *et coll.* (1966), however, evaluated the damage to the blood brain barrier in dogs following injections into the internal carotid artery and found that only 43 % of the animals had lesions of the blood brain barrier after Hypaque 50 % (sodium) as compared to 75 % after meglumine diatrizoate. These investigators employed the distribution of the lesion as a measure of the neurotoxicity instead of the degree of lesion. The diverging results might have been due to the different principles of evaluation of the degree of lesion of the barrier. Concerning the methylglucamine salts, we found Meglumine Conray 60 % somewhat more toxic than meglumine diatrizoate 60 %. Urografin, which is a methylglucamine salt with some addition of a sodium salt, also belongs to the group of low toxicity in the studies, when used in 60 % solution. When, however, its concentration was increased to 76 %, the toxicity increased considerably.

GONSETTE & ANDRE BALISAUX (1967) found the following contrast media to be equally toxic: Urografin 60 %, Meglumine Conray 60 %, Isopaque Cerebral 60 % and Sodium Isopaque 43 % (balanced with Ca and Mg). SALVESEN *et coll.* (1967b) reported, in accordance with our studies, that Meglumine Conray was more toxic than Isopaque Cerebral. They stated, however, that Urografin 60 % was somewhat more toxic than Isopaque Cerebral. These investigators were also able to demonstrate that a suitable addition of calcium salt to methylglucamine metrizoate diminished the toxicity as compared to the pure methylglucamine salt. A corresponding calcium salt addition to methylglucamine diatrizoate is not possible due to the low solubility of the calcium diatrizoate.

In spite of the standardized injection technique used, and although each animal was thoroughly examined for the presence of an anomalous occipital artery, there was still a large variation in the degree of lesion of the blood brain barrier at a certain amount of contrast medium. The range of body temperature was

too small to explain these differences (JEPSSON 1962). The discrepancy in the degree of lesion of the barrier in animals that received the same dose might be due to a difference in the vulnerability of the blood-brain barrier of the individual animals. It is therefore necessary to test each dose on at least three animals.

SUMMARY

The toxicity of certain modern roentgen contrast media was studied with selective injection into the internal carotid artery of rabbits and evaluated by damage to the blood brain barrier and cardiovascular reactions. The latter (initial hypotension and bradycardia) were severe for contrast media containing pure sodium salts but were not necessarily a measure of the neurotoxicity as estimated by studies of the barrier.

ZUSAMMENFASSUNG

Die Toxizität verschiedener moderner Kontrastmittel wurde bei selektiver Injektion der Carotis interna in Kaninchen durch Beurteilung der Beschädigung der Bluthirnschranke und der kardiovaskulären Störungen analysiert. Hochgradige kardiovaskuläre Störungen (Hypotonie und Bradykardie) wurden mit den Kontrastmitteln die reine Natriumsalze enthalten beobachtet ohne jedoch notwendigerweise als ein Mass der Neurotoxizität mit Hinsicht auf die Bluthirnschranke betrachtet zu werden.

RÉSUMÉ

Les auteurs ont étudié la toxicité de certains moyens de contraste radiologique modernes par l'injection sélective de l'artère carotide interne de lapins et l'ont évaluée par les dommages de la barrière hématoencéphalique et par les réactions cardiovasculaires. Ces réactions (hypertension initiale et bradycardie) ont été graves avec les moyens de contraste contenant des sels de sodium purs mais ne mesurent pas nécessairement la neurotoxicité estimée d'après les études de la barrière hématoencéphalique.

REFERENCES

- ASK UPMARK E. The carotid sinus and the cerebral circulation. *Acta psychiat. scand.* (1935) Suppl. No. 6.
- BAKAY L. The blood brain barrier. Charles C. Thomas, Springfield, 1956.
- BASSETT R. C., ROGERS J. S., CHERRY G. R. and GRUZHIT C. The effect of contrast media on the blood brain barrier. *J. Neurosurg.* 10 (1953) 38.
- BLOOR B. M., WRENN JR. F. R. and MARGOLIS G. An experimental evaluation of certain contrast media used for cerebral angiography. Electroencephalographic and histopathological correlations. *J. Neurosurg.* 8 (1951) 585.
- BROMAN T. and OLSSON O. The tolerance of cerebral blood vessels to a contrast medium of the Diodrast group. *Acta radiol.* 30 (1948) 326.
- — Technique for the pharmacodynamic investigation of contrast media for cerebral angiography. *Acta radiol.* 45 (1956) 96.

- CLEMENTZ H and OLIN T Apparatus for controlled infusion of saline in angiography and contrast in lymphangiography *Acta radiol* 55 (1961), 109
- CORNELL S H and FISCHER H W Comparison of mixtures of metrizoate and iothalamate salts with their methylglucamine solutions by the carotid injection technique *Invest Radiol* 2 (1967), 41
- CRAYER B N, CHUNG CHIN, HESS S M and SWOAP J R Penetration through the blood brain barriers of cats after intracarotid injections of ^{223}Na sodium diatrizoate plus parabens and the retention of ^{125}I methylglucamine diatrizoate in the blood of rats *Radiology* 90 (1968), 142
- EDSTROM R Citrate buffered $^{51}\text{CrCl}_3$ — an indicator of blood brain barrier damage — experimentally compared with ITHA *Acta psychiat scand* 36 (1961), 111
- FISCHER H W and CORNELL S H The toxicity of the sodium and methylglucamine salts of diatrizoate, iothalamate and metrizoate An experimental study of their circulatory effects following intracarotid injection *Radiology* 85 (1965), 1013
- and ECKSTEIN J W Comparison of cerebral angiographic contrast media by their circulatory effects An experimental study *Amer J Roentgenol* 86 (1961), 166
- GONSETTE R et ANDRE BALISAUX G La perméabilité des vaisseaux cérébraux Etude systématique de la tolérance des capillaires cérébraux pour les produits de contraste utilisés en artériographie *In* Cations in intravascular contrast media and development of specific metrizoate formulas, p 228 *Acta radiol* (1967) Suppl No 270
- GRETTZ T and TORNELL C Comparison of Isopaque sodium diatrizoate in intravascular contrast media and development of specific metrizoate formulas, p 75 *Acta radiol* (1967) Suppl No 270
- TELENS R and TORNELL G Influence of methylglucamine and calcium ions in metrizoate (Isopaque) on the bradycardial effect in carotid angiography *In* Cations in intravascular contrast media and development of specific metrizoate formulas, p 208 *Acta radiol* (1967) Suppl No 270
- HARRINGTON G, MICHEZ C, LYNCH P R et coll Blood brain barrier changes associated with unilateral cerebral angiography *Invest Radiol* 1 (1966), 431
- JEPSSON P G Studies on the blood brain barrier in hypothermia *Acta neurol scand* (1962) Suppl No 160
- and OLIN T Cerebral angiography in the rabbit *Lunds Universitets Årsskrift, N F Afd 2* 56 (1960) Nr 14
- KODAMA J K, BUTTLER W M, TUNG T W and HALLETT F P Iothalamate a new intravascular radio-opaque medium with unusual pharmacotoxic inertness *Exp molec Path* Suppl 2 (1963) 65
- LINDGREN P and TORNELL G Blood pressure and heart rate responses in carotid angiography with sodium acetrizoate (Triurof) An experimental study in cats *Acta radiol* 50 (1958), 160
- LUNDQVIST A and ENGELSTEN A (a) Polygraphic recordings of EEG, ECG and blood pressure during cerebral angiography with Isopaque III *In* Cations in intravascular contrast media and development of specific metrizoate formulas, p 87 *Acta radiol* (1967) Suppl No 270
- (b) Recordings of EEG, MCG, EMG and intra arterial blood pressure during cerebral angiography *In* Cations in intravascular contrast media and development of specific metrizoate formulas, p 198 *Acta radiol* (1967) Suppl No 270

- McCONNELL F and MERSEFAU W A The effect of angiographic contrast media on arterial endothelium. An experimental study. *J Canad Ass Radiol* 15 (1964) 14
- MARCOLIS G TINDALL G T, PHILLIPS R L et coll Evaluation of roentgen contrast agents used in cerebral arteriography. I A simple screening method. *J Neurosurg* 15 (1958) 30
- MOORE G E Diagnosis and localization of brain tumours. Charles C Thomas Springfield 1953
- OLIN T B and REDMAN H C Experimental evaluation of contrast media in the vertebral circulation. In Cations in intravascular contrast media and development of specific metrizoate formulas p 216. *Acta radiol* (1967) Suppl No 270
- SALVENSEN S, LUND NILSEN P and HOLTERMANN H (a) Ameliorating effects of calcium and magnesium ions on the toxicity of Isopaque sodium. In Cations in intravascular contrast media and development of specific metrizoate formulas p 17. *Acta radiol* (1967) Suppl No 270
- — — (b) Effects of calcium and magnesium ions on the systemic and local toxicities of the N-methylglucamine (meeglumine) salt of metrizoic acid (Isopaque). In Cations in intravascular contrast media and development of specific metrizoate formulas p 180. *Acta radiol* (1967) Suppl No 270
- SMITH G A CAUDILL C M MOORE G E et coll Experimental evaluation of cerebral angiography. *J Neurosurg* 8 (1951) 556
- SNOLIA E A and NASH F P Cerebral angiography. A brief outline of its history and experiences with Conray, a new contrast medium. *Vasc Dis* 1 (1964) 21
- STENWALL O An improved technique for testing the effect of contrast media and other substances on the blood brain barrier. *Acta radiol* 49 (1958) 281
- and KLATZO I Double tracer methods in studies on blood brain barrier dysfunction and brain edema. *Acta neurol scand* (1965) Suppl No 13 part 2 p 591
- TORNELL G Bradycardial reactions in cerebral angiography induced by sodium and methyl glucamine iothalamate (Conray). Comparison with Urografin in a controlled study in man. *Acta radiol Diagnosis* 7 (1968) 489
- Spinal cord tolerance to roentgen contrast media particularly during aortography with temporary occlusion of the aorta. An experimental investigation in dogs. *Acta radiol Diagnosis* II (1969) 257
- WHITTELEATHER J E and DESAUSSEURE R L Experience with a new contrast medium (Hypaque) for cerebral angiography. *Radiology* 67 (1956) 537

ARTERIOGRAPHIC APPEARANCES OF PHAECHROMOCYTOMAS

by

L O LANNER and M ROSECRANTZ

Recent progress in the investigation of arterial hypertension has resulted in biochemical and pharmacologic tests, making it possible to select cases harbouring a hormonally active tumour, such as the phaeochromocytoma. Although paroxysmal hypertension is a characteristic feature of phaeochromocytomas, cases with mainly sustained hypertension are not uncommon (Fig 1). The diagnosis, based on clinical and laboratory tests, is generally accurate. Cases exist, however, in which the laboratory data, probably as a consequence of intermittent secretion of pressure agents, do not support the clinical findings.

The main task of the radiologist is therefore to localize the tumour and in some cases also to establish the diagnosis. As aortography has become almost a routine procedure in the evaluation of arterial hypertension, and hormonal analyses are not always made, the phaeochromocytoma may be an unexpected radiologic finding. Knowledge of the radiographic appearances of these tumours and of the hazards of the examinations is therefore of importance.

Phaeochromocytomas arise from chromaffin tissue, mainly of the adrenal medulla and the paraganglia. About 90 per cent of all phaeochromocytomas occur in the adrenals and their proximity, the location next common is para-

- McCONNELL F and MERSERFAU W A The effect of angiographic contrast media on arterial endothelium An experimental study J Canad Ass Radiol 15 (1964), 14
- MARGOLIS G, TINDALL G T, PHILLIPS R L et coll Evaluation of roentgen contrast agents used in cerebral arteriography I A simple screening method J Neurosurg 15 (1958), 30
- MOORE G E Diagnosis and localization of brain tumours Charles C Thomas, Springfield 1953
- OLIN T II and REDMAN H C Experimental evaluation of contrast media in the vertebral circulation In Cations in intravascular contrast media and development of specific metrizoate formulas, p 216 Acta radiol (1967) Suppl No 270
- SALVESEN S, LUND NILSEN P and HOLTERMAN H (a) Ameliorating effects of calcium and magnesium ions on the toxicity of Isopaque sodium In Cations in intravascular contrast media and development of specific metrizoate formulas, p 17 Acta radiol (1967) Suppl No 270
- — — (b) Effects of calcium and magnesium ions on the systemic and local toxicities of the N-methylglucamine (meeglumine) salt of metrizoic acid (Isopaque) In Cations in intravascular contrast media and development of specific metrizoate formulas, p 180 Acta radiol (1967) Suppl No 270
- SMITH G A, CAUDILL C M, MOORE G E et coll Experimental evaluation of cerebral angiography J Neurosurg 8 (1951), 556
- SMOLIK E A and NASH F P Cerebral angiography A brief outline of its history and experiences with Conray, a new contrast medium Vasc Dis 1 (1964), 21
- STEINWALL O An improved technique for testing the effect of contrast media and other substances on the blood-brain barrier Acta radiol 49 (1958), 281
- and KLATZO J Double tracer methods in studies on blood brain barrier dysfunction and brain edema Acta neurol scand (1965) Suppl No 13, part 2 p 591
- TORNELL G Bradycardial reactions in cerebral angiography induced by sodium and methylglucamine iothalamate (Conray) Comparison with Urografin in a controlled study in man Acta radiol Diagnosis 7 (1968), 489
- Spinal cord tolerance to roentgen contrast media particularly during aortography with temporary occlusion of the aorta An experimental investigation in dogs Acta radiol Diagnosis 8 (1969), 257
- WHITELEATHER J E and DESAUSURE R L Experience with a new contrast medium (Hypaque) for cerebral angiography Radiology 67 (1956), 537



Fig 2 Extra adrenal phaeochromocytoma fed by branches of the renal and inferior phrenic arteries (\rightarrow) running at the periphery of the tumour which was situated medial to the right adrenal gland behind the vena cava. The inferior phrenic artery (\rightarrow) filled via anastomosis from the inferior suprarenal artery. The tumour could not be seen at exploration of the adrenal region: the exploration was then extended to the retrocaval space.

KUHLER & HOLST 1966, ROSSI et coll 1966, 1968, FRY et coll 1967, KAHN et coll 1967).

In our hospital, angiographies have been performed in all cases operated upon since 1950. Retroperitoneal pneumography has on the other hand only been carried out in about a third of the cases. We have now reviewed all the angiographic examinations with a view to find out with what accuracy the phaeochromocytomas can be demonstrated and if they possess characteristic vascularity.

Material. This comprises 26 cases, 13 females and 13 males, with 27 growths (Fig 1), the mean age being 42 years (23 to 65 years). The symptoms in three women appeared during the last month of pregnancy and in two of these removal

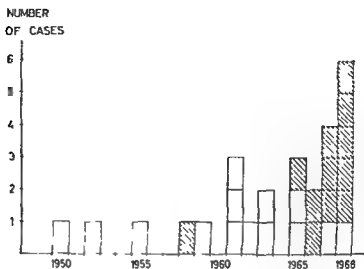


Fig 1 Pheochromocytomas examined and operated on in the period 1950—1968: crises with paroxysmal signs (unfilled columns) and crises with mainly sustained hypertension (hatched columns)

aortically along the sympathetic chain. Rare sites, such as the urinary bladder (SIVAK 1961), the neck and even the skull, have been reported.

The tumour occasionally appears in survey films as a soft tissue mass, or the diagnosis may be suggested by the deformation or displacement of a kidney. Egg-shell calcifications have been reported to be almost specific (GRAINGER et coll 1967). In the overwhelming number of cases, however, the growth is demonstrated only by contrast medium techniques, such as angiography or retroperitoneal pneumography.

The pheochromocytomas are 'high-explosive' neoplasms with a great tendency to release adrenalin or noradrenalin even by slight manipulations such as palpation of the abdomen or roentgen examinations. Opinions vary regarding the most appropriate way to localize these growths. Some authors, because of the risks of hypertensive crises, have suggested that specialized radiologic examinations should not be carried out, especially since in a number of cases (10 to 20 %) there are multiple pheochromocytomas which, even if one of them has been localized, require extensive exploration (SJOERDSEMA et coll 1966). Most authors are however of the opinion that the planning of surgical procedures is simplified if the tumour is demonstrated in one way or other. Retroperitoneal pneumography has been the method most commonly used. A number of papers illustrating the usefulness of angiography in the demonstration of pheochromocytomas have been published in recent years (ELFVIN 1959, BOIJSEN et coll 1966,



Fig 4 a) Right side phaeochromocytoma with faint accumulation of contrast medium and capsular veins (\rightarrow) b) Left side phaeochromocytoma (\rightarrow) in the late arterial phase of aortography. The tumour vessels are arranged like irregular meshes of a net

examined by the translumbar approach and in the remaining cases the percutaneous retrograde transfemoral technique was used.

Polythene catheters and a fairly small amount of a 50 % contrast medium were employed prior to 1959 (two cases in all). After 1959, the aortographies were performed with Ödman-Ledin catheters or up-occluded teflon catheters with side holes. At least 50 ml of Urografin 60 % were administered with a Gidlund-Elmja injector. Equipment for stereo-angiography was also utilized at this time, and in all cases, except those examined with the translumbar technique, an AOT film changer was used.

The blood pressure was continuously recorded throughout the examinations, and vein cannulas were inserted for immediate regitine injections in case of imminent hypertensive crises. The endocrinologist in charge of the case was always present during the procedure. After 1964, all cases examined for phaeochromocytoma were prepared with phenox benzamine hydrochloride (dibenzylamine) which, like regitine, is an alpha adrenergic blocking agent but has a more protracted effect than regitine. Complications of any importance were not encountered neither before nor after the introduction of dibenzylamine.

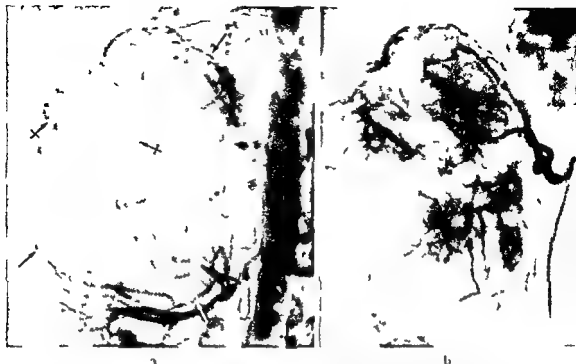


Fig 3 Aortography (a) and selective injection of a considerably widened inferior phrenic artery (b) in a case with large pheochromocytoma (1 500 g). The feeding arteries (\rightarrow) coursed at the periphery of the tumour and sent branches towards its centre. There were vessels (\leftrightarrow) probably mainly veins that filled in the arterial phase.

of the tumour was combined with Caesarean section. In the third woman, with bilateral neoplasms, clinical and radiologic examinations and surgery were performed shortly after spontaneous delivery.

All the tumours were situated in or contiguous to the adrenals, fifteen on the right and twelve on the left side. One of the masses was entirely extra-adrenal, medial to the right gland and retrocaval (Fig 2). Two of the others were separated from the adrenal glands but connected to them by thin fibrous strands. Considerable variations in size and weight of the tumours were recorded, the weight ranging from 11 to 1 500 grams. No correlation could be established between the size of the tumour and the hormonal activity.

Microscopy disclosed typical features of benign pheochromocytomas. Different degrees of degenerative changes with necrosis and cysts were the rule.

Angiographic technique As the study extends over a period as long as 18 years, the quality of the angiograms differed in the early and the late cases. Contrast media, as well as the technique of their injection, film changers and roentgen tubes have improved considerably during this time. Two of the early cases were



a



b



c

to the upper renal pole (→) could be demonstrated

to the upper renal pole (→) could be demonstrated

to the upper renal pole (→) could be demonstrated

provocative histamine test a blood sample from the left renal vein indicated a marked increase in nor-adrenaline

The material includes two cases with false positive diagnoses. In both, a left-side growth, in addition to the correctly diagnosed tumour on the right side, was considered probable. In one of the cases, retroperitoneal pneumography revealed a mass close to the left upper renal pole, probably explained by marked irregular-

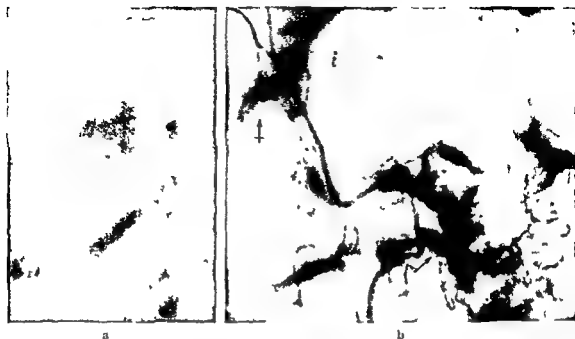


Fig 5 a) Highly vascularized right side pheochromocytoma homogenous accumulation of contrast medium in the venous phase b) The complex arterial supply of the adrenals is illustrated by a left side pheochromocytoma supplied by branches from the first part of the right inferior phrenic artery (→) which arose from the left side of the aorta. There were branches also to the normal right adrenal gland (↔)

Results

Eight of the twenty-seven tumours were not diagnosed preoperatively by angiography. Two of these had slight but significant angiographic changes that were overlooked. In the remaining six cases, angiographic localization was not possible even on retrospective viewing. In three of these cases, belonging to the early part of the material, the angiographic examinations were incomplete. The tumour in these cases and in an additional case was demonstrated by retroperitoneal pneumography. Thus two angiographically negative cases remain. One was of a pregnant woman in whom exploration combined with Caesarean section was made without further diagnostic procedures. The tumour was small and situated totally within the adrenal gland, visible only after division of the gland. The tumour was small also in the second case, its diameter being about 2 cm, it lay in the angle between the aorta and the left renal artery and arose from an ectopic adrenal gland. Retroperitoneal pneumography suggested a normal adrenal gland and no mass was seen. Selective adrenal phlebography was attempted but without success. Blood specimens were taken during the examination. After a



Fig. 3 Left side pheochromocytoma situated almost totally in front of the upper renal pole. At aortography the tumour was difficult to identify in the arterial phase (a) because of superimposition of renal vessels, in the venous phase (b) the tumour was delineated by capsular veins (\rightarrow). At retroperitoneal pneumography (lateral tomogram) (c) the relation of the tumour (\rightarrow) to the upper renal pole (\leftrightarrow) could be demonstrated.

provocative histamine test a blood sample from the left renal vein indicated a marked increase in noradrenaline.

The material includes two cases with false positive diagnoses. In both, a left-side growth, in addition to the correctly diagnosed tumour on the right side.



Fig 5 a) Highly vascularized right side pheochromocytoma, homogenous accumulation of contrast medium in the venous phase b) The complex arterial supply of the adrenals is illustrated by a left side pheochromocytoma supplied by branches from the first part of the right inferior phrenic artery (\rightarrow) which arose from the left side of the aorta. There were branches also to the normal right adrenal gland (\rightarrow)

Results

Eight of the twenty-seven tumours were not diagnosed preoperatively by angiography. Two of these had slight but significant angiographic changes that were overlooked. In the remaining six cases, angiographic localization was not possible even on retrospective viewing. In three of these cases, belonging to the early part of the material, the angiographic examinations were incomplete. The tumour in these cases and in an additional case was demonstrated by retroperitoneal pneumography. Thus, two angiographically negative cases remain. One was of a pregnant woman in whom exploration combined with Caesarean section was made without further diagnostic procedures. The tumour was small and situated totally within the adrenal gland, visible only after division of the gland. The tumour was small also in the second case, its diameter being about 2 cm, it lay in the angle between the aorta and the left renal artery and arose from an ectopic adrenal gland. Retroperitoneal pneumography suggested a normal adrenal gland and no mass was seen. Selective adrenal phlebography was attempted but without success. Blood specimens were taken during the examination. After a



Fig. 8. Left-side phaeochromocytoma visible only at selective angiography: a) aortography; b) and c) Selective injection of the renal artery. There are tumour vessels (\rightarrow) only within a small area in (b). In the venous phase (c) a capsular vein (\leftrightarrow) is clearly seen.

that no vascular pattern could be identified. These growths appeared in a late phase as homogenous accumulations of contrast medium (Fig. 5a). In a few cases the neoplasms were less vascularized, having a conglomerate of minute tortuous arteries within a small area only (Fig. 8b). A few wide irregular vessels, mainly resembling veins, were observed in the arterial phase in several cases, especially in those with large tumours (Fig. 3a). Less vascularized areas were seen in all growths rich in vessels, probably due to the aforementioned degenerative changes with necrosis and cysts.

Discussion

ROSS, YOUNG & PARKER (1968) stated angiography is an effective method for the localization of phaeochromocytomas. They based this statement on 99 cases, twelve of their own — up to now the largest published number of cases examined angiographically — and the remainder collected from the literature. The same conclusion may be drawn from the present material which comprises 27 neoplasms, most of which were demonstrated at angiography. The angiographic diagnosis is in many cases difficult, especially in small tumours, the main cause being the complex and variable arterial supply of the adrenal glands (MERKLEY & MICHELS 1958). The supply is derived from many small arteries of different origin, usually the renal arteries, the aorta and the inferior phrenic arteries, the

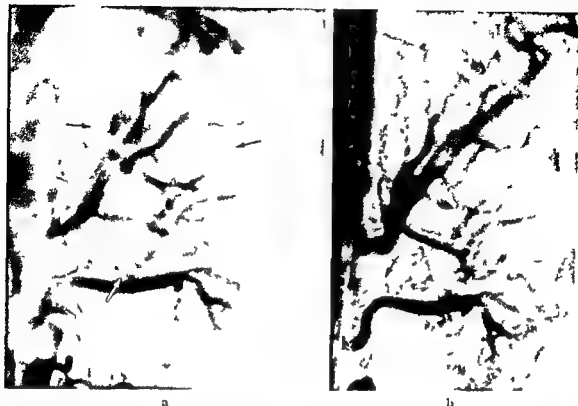


Fig 7 Large left side phaeochromocytoma in front of the kidney a) The tumour (\rightarrow) was partly superimposed by renal vessels b) A small tortuous feeding artery (\leftrightarrow) coming directly from the aorta enabled the diagnosis to be made (subtraction film)

ity of the renal pole, with deep retractions which most likely were due to pyelonephritic lesions. In the second case, a fairly large branch from the left renal artery suggested a hypertrophic suprarenal artery. Definite tumour vessels were not seen. No gas study was performed.

The angiographic appearances of the phaeochromocytomas were fairly characteristic, although not uniform. The feeding arteries in practically all the cases followed the periphery of the neoplasm (Figs 2 and 3). A characteristic feature of these arteries was that they maintained almost the same calibre around the tumour. Wide veins, probably capsular veins, encircling the mass (Figs 4a, 6b and 8c), was a constant finding. Four different types of vascular pattern within the tumours may be recognized in the material.

In some cases, branches from the peripheral arteries, resembling the spokes of a wheel, converged towards the centre of the tumour (Fig 3). These branches in other cases had a reticulated arrangement like irregular meshes of a net (Fig 4b). The arteries, especially in small tumours, were sometimes so abundant



Fig 8 Left side phaeochromocytoma visible only at selective angiography: a) Aortography b) and c) Selective injection of the renal artery. There are tumour vessels (\rightarrow) only within a small area in (b). In the venous phase (c) a capillary vein (\longleftrightarrow) is clearly seen.

that no vascular pattern could be identified. These growths appeared in a late phase as homogenous accumulations of contrast medium (Fig 5a). In a few cases the neoplasms were less vascularized, having a conglomerate of minute tortuous arteries within a small area only (Fig 8b). A few wide irregular vessels, mainly

vessels, probably due to the aforementioned degenerative changes with necrosis and cysts.

Discussion

ROSS, YOUNG & PANKE (1968) stated 'angiography is an effective method for the localization of phaeochromocytomas'. They based this statement on 99 cases, twelve of their own — up to now the largest published number of cases examined angiographically — and the remainder collected from the literature. The same conclusion may be drawn from the present material which comprises 27 neoplasms, most of which were demonstrated at angiography. The angiographic diagnosis is in many cases difficult, especially in small tumours, the main cause being the complex and variable arterial supply of the adrenal glands (MERKLEY & MICHELS 1958). The supply is derived from many small arteries of different origin, usually the renal arteries, the aorta and the inferior phrenic arteries, the



FIG. 9

in pheochromocytomas



Fig 10 Adrenal carcinoma with Cushing's syndrome. There are feeding arteries at the periphery of the tumour and irregular vessels in the medial part of the otherwise poorly vascularized growth.

other possible supplementary sources being the lumbar, the ureteric and the gonadal arteries. The inferior phrenic artery may arise from the aorta, from the coeliac artery or one of its branches or from the renal or lumbar arteries (Fig 5b). To ensure demonstration of all the suprarenal arteries the deposition of the contrast medium must be made in the aorta, above the origin of the coeliac artery. Superimposition of a great number of coeliac and mesenteric branches makes identification of the very narrow suprarenal arteries difficult.

The tumours on the right side are most often situated above the upper renal pole, usually deforming it and displacing the kidney in a typical way. The growths may, however, extend caudally in front of and medial to the kidney, between it and the vena cava. On the left side the tumours are usually located partly or entirely in front of the upper renal pole (Fig 6). The neoplasm in one of the cases lay as low as the hilum of the kidney (Fig 7). Superimposition in these cases of not only coeliac and mesenteric but also of renal branches makes the angiographic diagnosis even more difficult. Some of the problems caused by superimposition of arterial branches may be overcome by angiography in different projections. The blocking treatment with dibenzylamine has encouraged us to perform repeated injections into the aorta as well as selective angiographies



Fig 11 Selective angiography of the renal artery

plasma

With high quality films obtained in different projections most phaeochromocytomas can usually be demonstrated at aortography. In one of the cases in which aortography as well as selective angiography were performed (Fig 8), the tumour could be demonstrated only in the selective examination. Obvious changes in several other cases appeared only after selective injection even though they could be detected in retrospect in the aortograms. We therefore feel that the examination should proceed with selective angiography whether or not a possible lesion is found. The suprarenal arteries cannot be catheterized unless pathologically widened. By selective suprarenal arteriography is meant contrast injection into one of the large arteries from which the suprarenal arteries arise: the renal, the inferior phrenic and the coeliac arteries. The suprarenal arteries that are most easily examined are those arising from the renal arteries. Catheters with side holes are employed to ensure filling of the inferior suprarenal arteries.

which often spring from the very first portion of the renal artery (Figs 2 and 8b). The inferior phrenic artery with the superior suprarenal branches, mostly arising directly from the aorta, can often be catheterized (Figs 3b and 5b). If a tumour is demonstrated at aortography, and the adrenal region of the opposite side cannot be evaluated with certainty, selective examination should be made on that side since the phaeochromocytomas may be bilateral. Even if no tumour can be observed, in spite of careful examinations, a small avascular mass or one outside the suprarenals may still be present.

Retroperitoneal pneumography was performed in those cases in which no neoplasm could be demonstrated at angiography. One small tumour, not visible at angiography, could thus be demonstrated. The accuracy of the two methods cannot be compared since retroperitoneal pneumography was not performed in all cases. Retroperitoneal pneumography does not reveal the nature and origin of a new growth and normal structures may be mistaken for pathologic masses. It is not always possible to direct the gas to the suprarenal areas, probably because of retroperitoneal adhesions secondary to haemorrhages around highly vascularized tumours. An advantage of angiography is the possibility of demonstrating neoplasms in regions outside the adrenal glands (Fig. 2).

Tumours within or close to the right adrenal gland sometimes make impressions in the inferior vena cava and may be demonstrated by inferior vena cavography (LUND *et coll.* 1960). Blood samples for determination of catecholamines should be obtained at different levels during the procedure, preferably before and after provocative histamine tests.

The angiographic appearances of phaeochromocytomas were discussed by BOIJSEN *et coll.* (1966) and ROSSI *et coll.* (1966, 1968). Rossi has stated that benign phaeochromocytomas lead to typical angiographic appearances, with hypertrophy of the suprarenal arteries and a finely reticulated network of small arteries in the early arterial phase. An homogeneous accumulation of contrast medium, in which there may be zones of decreased vascularity, appears in the capillary phase. This is in general agreement with the present findings. We would however like to stress that the vascularity varies considerably. In many cases there is no accumulation of contrast medium within the tumour but the course of the feeding arteries around the periphery of the tumour is typical and wide capsular veins are rarely absent. LAGERGREN (1967) examined six cases of phaeochromocytomas by microangiography. He encountered hypervascularity in only one case and was of the opinion that the vascular pattern in the other cases could not be distinguished from that of adenomas, neither by clinical angiography nor by microangiography.

The angiographic appearances of the phaeochromocytomas in the present material were compared with those of other adrenal growths, eight adenomas and

nine carcinomas. It is true that all adrenal tumours have many characteristics in common such as supply arteries following the periphery, but the vascularity of benign phaeochromocytomas was different from that of other adrenal neoplasms. The vessels in the small adenomas were narrow and irregular with no characteristic pattern (Fig 9). Large adenomas as well as carcinomas were fairly poor in vessels but with small areas of irregular tumour vessels (Fig 10). Wide irregular veins and venous lakes, irregularly scattered in the growths, was a characteristic finding (Fig 11). The problem of the differential diagnosis is however of minor importance since the nature of adrenal neoplasms can be determined by hormonal analysis.

Conclusions

It is usually possible to verify the diagnosis and locate phaeochromocytomas with arteriography. Small tumours, especially if poorly vascularized or situated totally within the adrenal glands, may be impossible to demonstrate. The arteriographic diagnosis is often difficult and requires, besides experience, a proper technique with high film quality, several projections and selective injections.

Acknowledgements

The authors wish to thank Docent B. Sjogren and Dr L. Ohlsson of the Department of Endocrinology who made the clinical examinations, and Docent H. Ekman of the Department of Urology who operated on the cases.

SUMMARY

The arteriographic appearances of phaeochromocytomas based on the examinations of 26 cases with 27 tumours are discussed. All the growths were benign and situated in or contiguous to the adrenal glands. The vascularity which is fairly characteristic, is compared to that of other adrenal tumours.

ZUSAMMENFASSUNG

Die arteriographischen Befunde wurden in 26 Fällen mit 27 Phaeochromocytomen analysiert. Alle Geschwülste waren gutartig und entweder innerhalb oder wenigstens nahe den Nebennieren lokalisiert. Das Gefäßbild, das ziemlich charakteristisch ist, wurde mit dem anderer Nebennierentumoren verglichen.

RÉSUMÉ

Les auteurs examinent les signes arteriographiques des phaeochromocytomes en se basant sur l'examen de 26 cas presentant 27 tumeurs. Toutes ces tumeurs étaient benignes et étaient situées dans les glandes surrenales ou leurs étaient contigues. Ils comparent leur vascularisation qui est assez caractéristique à celle d'autres tumeurs surrenales.

which often spring from the very first portion of the renal artery (Figs 2 and 8b) The inferior phrenic artery with the superior suprarenal branches, mostly arising directly from the aorta, can often be catheterized (Figs 3b and 5b) If a tumour is demonstrated at aortography, and the adrenal region of the opposite side cannot be evaluated with certainty, selective examination should be made on that side since the phaeochromocytomas may be bilateral Even if no tumour can be observed, in spite of careful examinations, a small avascular mass or one outside the suprarenals may still be present

Retroperitoneal pneumography was performed in those cases in which no neoplasm could be demonstrated at angiography One small tumour, not visible at angiography, could thus be demonstrated The accuracy of the two methods cannot be compared since retroperitoneal pneumography was not performed in all cases Retroperitoneal pneumography does not reveal the nature and origin of a new growth and normal structures may be mistaken for pathologic masses It is not always possible to direct the gas to the suprarenal areas, probably because of retroperitoneal adhesions secondary to haemorrhages around highly vascularized tumours An advantage of angiography is the possibility of demonstrating neoplasms in regions outside the adrenal glands (Fig 2)

Tumours within or close to the right adrenal gland sometimes make impressions in the inferior vena cava and may be demonstrated by inferior vena cavography (LUND *et coll* 1960) Blood samples for determination of catecholamines should be obtained at different levels during the procedure, preferably before and after provocative histamine tests

The angiographic appearances of phaeochromocytomas were discussed by BOIJSEN *et coll* (1966) and ROSSI *et coll* (1966, 1968) ROSSI has stated that benign phaeochromocytomas lead to typical angiographic appearances, with hypertrophy of the suprarenal arteries and a finely reticulated network of small arteries in the early arterial phase An homogeneous accumulation of contrast medium, in which there may be zones of decreased vascularity, appears in the capillary phase This is in general agreement with the present findings We would however like to stress that the vascularity varies considerably in many cases there is no accumulation of contrast medium within the tumour but the course of the feeding arteries around the periphery of the tumour is typical and wide capsular veins are rarely absent LAGERGREN (1967) examined six cases of phaeochromocytomas by microangiography He encountered hypervascularity in only one case and was of the opinion that the vascular pattern in the other cases could not be distinguished from that of adenomas, neither by clinical angiography nor by microangiography

The angiographic appearances of the phaeochromocytomas in the present material were compared with those of other adrenal growths, eight adenomas and

nine carcinomas. It is true that all adrenal tumours have many characteristics in common, such as supply arteries following the periphery, but the vascularity of benign pheochromocytomas was different from that of other adrenal neoplasms. The vessels in the small adenomas were narrow and irregular with no characteristic pattern (Fig 9). Large adenomas as well as carcinomas were fairly poor in vessels but with small areas of irregular tumour vessels (Fig 10). Wide irregular veins and venous lakes, irregularly scattered in the growths, was a characteristic finding (Fig 11). The problem of the differential diagnosis is however of minor importance since the nature of adrenal neoplasms can be determined by hormonal analysis.

Conclusions

It is usually possible to verify the diagnosis and locate pheochromocytomas with arteriography. Small tumours, especially if poorly vascularized or situated totally within the adrenal glands, may be impossible to demonstrate. The arteriographic diagnosis is often difficult and requires, besides experience, a proper technique with high film quality, several projections and selective injections.

Acknowledgements

The authors are indebted to the Department of Endocrinology and the Department of Urology for their cooperation.

SUMMARY

The arteriographic appearances of pheochromocytomas based on the examinations of 26 cases with 27 tumours are discussed. All the growths were benign and situated in or contiguous to the adrenal glands. The vascularity which is fairly characteristic, is compared to that of other adrenal tumours.

ZUSAMMENFASSUNG

Die arteriographischen Befunde wurden in 26 Fällen mit 27 Phäochromocytomen analysiert. Alle Geschwülste waren gutartig und entweder innerhalb oder wenigstens nahe den Nebennieren lokalisiert. Das Gefäßbild, das ziemlich charakteristisch ist, wurde mit dem anderer Nebennierentumoren verglichen.

RÉSUMÉ

Les auteurs examinent les signes artériographiques des pheochromocytomes en se basant sur l'examen de 26 cas présentant 27 tumeurs. Toutes ces tumeurs étaient bénignes et étaient situées dans les glandes surrénales ou leurs étaient contigues. Ils comparent leur vascularisation qui est assez caractéristique, à celle d'autres tumeurs surrénales.

REFERENCES

- AHLBACK S The suprarenal glands in aortography *Acta radiol* 50 (1958), 341
- ASK UPMARK E, KNUTSSON P and THORÉY L Pheochromocytoma Diagnostic features *Acta med scand* 182 (1967), 673
- BOIJSEN E, WILLIAMS C M and JUDKINS M P Angiography of pheochromocytoma *Amer J Roentgenol* 98 (1966), 225
- BRAUN W C, PURYFAR W G and LANDIS R R Pheochromocytoma in pregnancy *J Urol* 76 (1956), 323
- EDSMAN G Angionephrography and suprarenal angiography A roentgenologic study of the normal kidney expansive renal and suprarenal lesions and renal aneurysms *Acta radiol* (1957) Suppl No 155
- ELFVIN P Roentgen findings in a case of pheochromocytoma *Acta radiol* 52 (1959), 461
- FRY I K, KERR I H, THOMAS M L and STARKER F The value of aortography in the diagnosis of pheochromocytoma *Clin Radiol* 18 (1967), 276
- GRAINGER R G, LLOYD G A S and WILLIAMS J L Egg shell calcification a sign of pheochromocytoma *Clin Radiol* 18 (1967), 282
- HOLMBERG S och ÖHLSSON L Diagnostik och behandling av feokromocytom (In Swedish) *Svenska Läk-Tidn* 65 (1968), 1659
- HOLST L R Pheochromocytoma demonstrated by aortography Report of two cases *Acta radiol* 57 (1962), 259
- KAHN P C Selective angiography of the inferior phrenic arteries *Radiology* 88 (1967), 1
- and NICKROSE L V Selective angiography of the adrenal glands *Amer J Roentgenol* 101 (1967), 739
- KOHLER R and HOLST L R Angiographic localization of suprarenal tumours *Acta radiol Diagnosis* 4 (1966), 21
- LACROIX C Angiographic changes in the adrenal glands *Amer J Roentgenol* 101 (1967), 732
- LUND R, GARCIA III N A, LE BLANC G A et coll Inferior vena cavography in preoperative localization of pheochromocytoma *J Urol* 83 (1960), 768
- MERKLIN R J and MICHELS N A The variant renal and suprarenal blood supply with data on the inferior phrenic ureteral and gonadal arteries *J Int Coll Surg* 29 (1958), 41
- MIKALSSON C G Retrograde phlebography of both adrenal veins A preliminary report *Acta radiol Diagnosis* 6 (1967), 348
- Epinephro phlebography in two cases of Conn's syndrome *Acta radiol Diagnosis* 7 (1968), 410
- MUNSTER W, WIERNY L und FORSTMANN W Angiographie der Nebennieren Tumoren *Fortschr Röntgenstr* 101 (1966), 367
- PENDERGRASS H P Retroperitoneal radiography Roentgen techniques to demonstrate pheochromocytomas and other retroperitoneal masses *Radiol Clin N Amer* 1 (1963), 195
- FORSTMANN W, WIERNY L und MUNSTER W Die selektive Nebennierenangiographie *Fortschr Röntgenstr* 101 (1966), 150
- ROSSI P Arteriography in adrenal tumours *Brit J Radiol* 41 (1968), 81
- YOUNG I S and PANKE W F Techniques usefulness and hazards of arteriography of pheochromocytoma *J Amer med Ass* 205 (1968), 547
- KAUFMAN L, RUZICKA F F and PANKE W Angiographic localization of pheochromocytoma *Radiology* 86 (1966), 266
- SIVAK G C Pheochromocytoma of bladder *J Urol* 86 (1961), 568
- SJOERDIMA A, ENGELMAN K, WALDMANN T A et coll Pheochromocytoma Current concepts of diagnosis and treatment *Ann intern Med* 65 (1966), 1302

MICROANGIOGRAPHY OF THE RENAL VESSELS IN RABBIT

Comparison of different methods

by

HEIKKI WENDELIN and ILMARI LINDGREN

The aim in renal microangiography is to obtain complete contrast filling of certain vessels. The results are influenced by various inter related factors, which have been widely discussed in the literature (BARCLAY 1951, BELLMAN 1953, HERZOG 1957, and RUBIN 1964). Most authors agree that the infusion pressure should be close to the physiologic blood pressure limits that correspond to the vessel to be infused. The injection time may vary from a few minutes to several hours (LJUNGQVIST 1963).

The usual contrast media have recently been replaced by suspensions of BaSO_4 in various concentrations. This is a particulate medium and technical aspects in the preparation of the suspension must therefore be taken into account (KORMANO 1967). A similar type of particulate contrast medium of high density has recently been introduced, it has the advantage of being brightly colored and

unlike heavy metal salts. The particle size is said to be less than 1 micron. (The precise nature of Chromopaque has not been disclosed.)

Submitted for publication 7 January 1969

REFERENCES

- AHLBACK S The suprarenal glands in aortography *Acta radiol* 50 (1958), 341
- ASK UPMARK F, KNUTSSON F and THORÉN L Pheochromocytoma Diagnostic features *Acta med scand* 182 (1967), 673
- BOIJSEN E, WILLIAMS C M and JUDKINS M P Angiography of pheochromocytoma *Amer J Roentgenol* 98 (1966), 225
- BRAUN W C, PURDY W G and LANDES R R Pheochromocytoma in pregnancy *J Urol* 76 (1956), 323
- EDSMAN G Angionephrography and suprarenal angiography A roentgenologic study of the normal kidney, expansive renal and suprarenal lesions and renal aneurysms *Acta radiol* (1957) Suppl No 155
- ELFVIN P Roentgen findings in a case of phaeochromocytoma *Acta radiol* 52 (1959), 461
- FRY I K, KERR I H, THOMAS M L and STARRER F The value of aortography in the diagnosis of phaeochromocytoma *Clin Radiol* 18 (1967) 276
- GRAINGER R G, LLOYD G A S and WILLIAMS J L Egg shell calcification a sign of phaeochromocytoma *Clin Radiol* 18 (1967) 282
- HOLMBERG S och ÖHLSOHN L Diagnostik och behandling av feokromocytom (In Swedish) *Svenska Lak-Tidn* 65 (1968), 1659
- HOLSTI L R Phaeochromocytoma demonstrated by aortography Report of two cases *Acta radiol* 57 (1962) 259
- KAHN P C Selective angiography of the inferior phrenic arteries *Radiology* 88 (1967) 1
- and NICKROSE L V Selective angiography of the adrenal glands *Amer J Roentgenol* 101 (1967), 739
- KOHLER R and HOLSTI L R Angiographic localization of suprarenal tumours *Acta radiol* Diagnosis 4 (1966) 21
- LACERGREN C Angiographic changes in the adrenal glands *Amer J Roentgenol* 101 (1967) 732
- LUND R R, GARCIA III N A, LE BIANC G A et coll Inferior vena cavography in preoperative localization of pheochromocytoma *J Urol* 83 (1960) 768
- MERLIN R J and MICHELS N A The variant renal and suprarenal blood supply with data on the inferior phrenic ureteral and gonadal arteries *J Int Coll Surg* 29 (1958) 41
- MIKAELSSON C G Retrograde phlebography of both adrenal veins A preliminary report *Acta radiol* Diagnosis 6 (1967) 348
- Epinephro phlebography in two cases of Conn's syndrome *Acta radiol* Diagnosis 7 (1968) 410
- MUNSTER W, WIERNY L und PORSTMANN W Angiographie der Nebennieren Tumoren *Fortschr Röntgenstr* 104 (1966), 367
- PENDERGRASS H P Retroperitoneal radiography Roentgen techniques to demonstrate pheochromocytomas and other retroperitoneal masses *Radiol Clin N Amer* 1 (1963) 195
- PORSTMANN W, WIERNY L und MUNSTER W Die selektive Nebennierenangiographie *Fortschr Röntgenstr* 104 (1966) 150
- ROSSI P Arteriography in adrenal tumours *Brit J Radiol* 41 (1968) 81
- YOUNG I S and PANKE W F Techniques, usefulness and hazards of arteriography of pheochromocytoma *J Amer med Ass* 205 (1968), 547
- KAUFMAN L, RUZICKA F F and PANKE W Angiographic localization of pheochromocytoma *Radiology* 86 (1966) 266
- SIVAK G C Pheochromocytoma of bladder *J Urol* 86 (1961) 568
- SJOERDMA A, ENGELMAN K, WALDMANN T A et coll Pheochromocytoma Current concepts of diagnosis and treatment *Ann Intern Med* 65 (1966) 1302

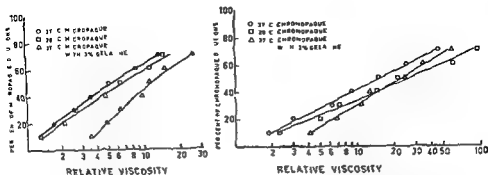


Fig 1 The relative viscosity values of Micropaque dilutions (a) and of Chromapaque dilutions (b) at different temperatures and percentages (the viscosity of distilled water taken as 1)

nulated with a polythene tube at laparotomy and the renal vein cut. The animals were heparinized (dose 5 000 I U) before anesthetization.

Specially prepared 250 ml bottles were used (Ljungqvist 1963). Because the contrast medium is particulate, the bottle was placed on a magnetic stirrer provided with a thermoregulator. The 100 mg Hg infusion pressure was kept constant with a liquid air flask and controlled with a Hg manometer, the infusion time was one hour, after which the flow ceased.

The contrast medium suspensions were diluted with physiologic saline to the required percentages. In some cases when the temperature was 37°C the contrast media contained 3% gelatine. The data of the experiments are given in a Table. The relative viscosity of the contrast media was measured with an Ostwald viscometer (Bull 1964).

The infusion was made at two different body temperatures +20°C and +37°C. The respective temperatures of the contrast media were kept the same. The infusion at +37°C was made while the animal was under anesthesia and until the animal died during the procedure. The infusion at +20°C was applied to fresh post mortem material. Furthermore, 4 kidneys were deep-frozen to -25°C and stored for several days, after which they were rewarmed to +20°C and infused with Chromapaque 10% at +20°C. This was done in order to study the vascular filling of the deep-frozen stored organs.

At least 2 kidneys were used in each experiment. After infusion the renal vessels were located.

of the formalin. After complete fixation the kidneys were cut frontally in series of 2 mm thick slices and radiographed for preliminary orientation on Kodak Contact Photomechanical Film. A Machlett AEG-50 roentgen

Table

Results obtained in the different experimental conditions

Contrast medium				Filling degrees of the renal vasculature of rabbit					
Suspension	Concen- tration	Tem- perature	Relat viscos- ity	Arcuate artery	Inter- lobular artery	Afferent arteriole	Arteriole in glom- erulus	Direct arteriole	Efferent arteriole
	°	C°		o 100 μ	o 50 μ	o 30 μ	o 10 μ	o 10 7 μ o 7—5 μ	
M	10	20	1.3	+++	+++	+++	+++	++	++
M	10	37	1.2	+++	+++	+++	+++	+++	+++
M with gelatine 3 %	10	37	3.7	+++	+++	+++	+++	+++	+++
M	40	20	4.3	+++	+++	0	0	0	0
M	40	37	3.6	+++	+++	+++	++	+	0
M with gelatine 3 %	40	37	8.5	+++	+++	+++	+++	++	+
C	10	20	2.3	+++	+++	+++	+++	++	+
C	10	37	2.0	+++	+++	+++	+++	+++	+++
C with gelatine 3 %	10	37	4.1	+++	+++	+++	+++	+++	+++
C	40	20	1.5	+++	+++	++	+	0	0
C	40	37	9.0	+++	+++	+++	++	+	0
C with gelatine 3 %	40	37	1.5	+++	+++	++	+	0	0

M — Micropaque C — Chromopaque +++ indicates complete, ++ moderate + sparse but detectable and 0 no filling of vessels

The purpose of the present investigation has been to compare a BaSO_4 suspension (Micropaque, Damancy & Co Ltd) and Chromopaque under certain physical conditions. The infusion pressure and time were kept constant. The variables studied were the viscosity, temperature and concentration of the contrast media. The rabbit kidney was chosen as a test organ because its vasculature has been well studied and the different degrees of its vascular filling can therefore readily be distinguished (RUBIN 1964, LJUNGVIST & LAGERGREN 1962).

Material and Methods The material consisted of 27 adult rabbits of both sexes weighing between 2.7 and 3.4 kg. The animals were anesthetized and killed with pentobarbitone sodium (Nembutal, Abbot). The renal artery was can-



Fig 3 Two microradiograms demonstrating the different degrees of renal vascular filling a) Chromopaque 10% at +37°C Complete filling as far as the efferent arterioles b) Chromopaque 40% at +37°C Complete filling of afferent arterioles and partial filling of the glomeruli The microradiograms are reproduced from the original ones $\times 100$

tube with 1.5 mm focus and equipped with a 1.5 mm thick beryllium window was employed, this was run at 30 kV. The slices were placed on a 0.5 mm plastic film which was in contact with the photographic material. The film focus distance was 1 meter.

After the preliminary examination, one slice was chosen for embedding in paraffin beeswax (4/1), and 150-micron sections were cut for contact microradiography. The same tube and kV were used, but the focus-film distance was decreased to 0.5 meter and the photographic material changed to Kodak Spectroscopic Plate 649 E or to Kodak Maximum Resolution Plate.

The different parts of the renal arterial and capillary pattern were identified in the micrograms and their minimum diameter was measured microscopically (see Table). The degree of contrast filling was also verified from an ordinary histologic section made from the original microradiographed section, 5 to 7 micron paraffin sections were taken and stained by conventional methods.

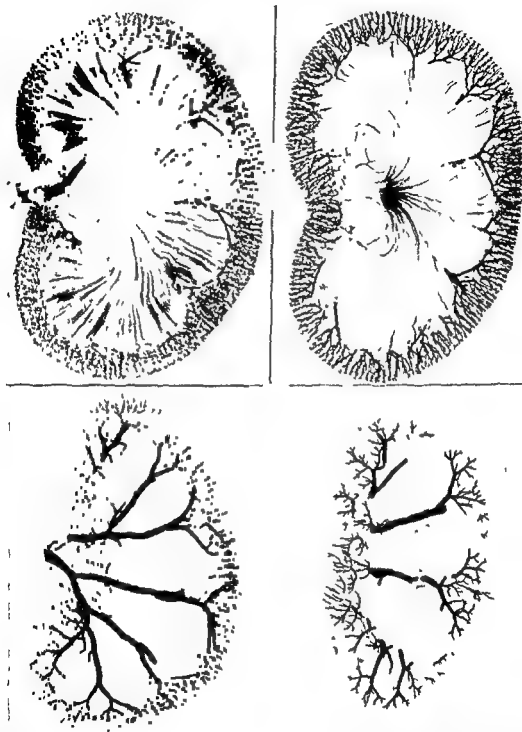


Fig 2 Different degrees of filling of the renal arterial vasculature of the rabbit
Upper left Chromopaque 10 % at 37° C Complete filling of arterial capillary vasculature
Upper right Micropaque 10 % at + 20° C Complete filling of the glomerular capillaries, moderate filling of the smaller capillaries
Lower left Micropaque 40 % at + 37° C Complete filling only as far as the afferent arterioles
Lower right Micropaque 40 % at + 20° C Complete filling only as far as the interlobular arteries



Fig 3 Two microradiograms demonstrating the different degrees of renal vascular filling a) Chromopaque 10% at +37°C Complete filling as far as the efferent arterioles b) Chromopaque 40% at +37°C Complete filling of afferent arterioles and partial filling of the glomeruli The microradiograms are reproduced from the original ones $\times 100$

tube with 1.5 mm focus and equipped with a 1.5 mm thick beryllium window was employed, this was run at 30 kV. The slices were placed on a 0.5 mm plastic film which was in contact with the photographic material. The film-focus distance was 1 meter.

After the preliminary examination, one slice was chosen for embedding in paraffin-beeswax (4/1), and 150 μ m sections were cut for contact microradiography. The same tube and kV were used, but the focus-film distance was decreased to 0.5 meter and the photographic material changed to Kodak Spectroscopic Plate 649-E or to Kodak Maximum Resolution Plate.

The different parts of the renal arterial and capillary pattern were identified in the micrograms and their minimum diameter was measured microscopically (see Table). The degree of contrast filling was also verified from an ordinary histologic section made from the original microradiographed section, 5 to 7 μ m paraffin sections were taken and stained by conventional methods.

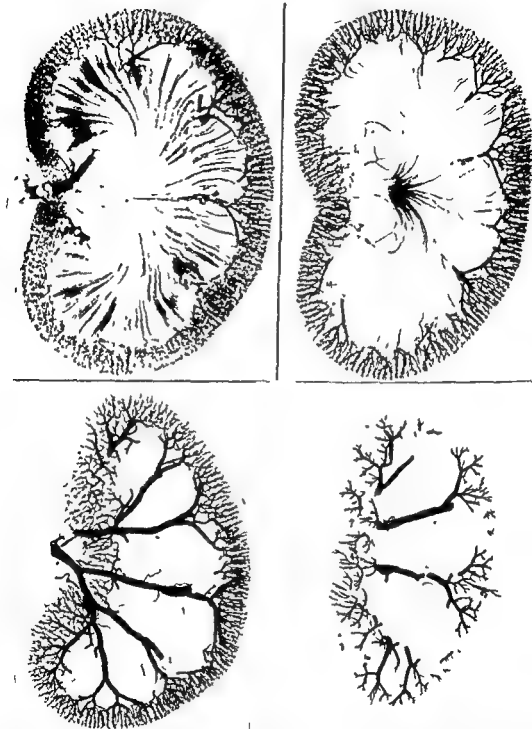


Fig 2 Different degrees of filling of the renal arterial vasculature of the rabbit
Upper left Chromopaque 10 % at 37° C Complete filling of arterial capillary vasculature
Upper right Micropaque III % at + 20° C Complete filling of the glomerular capillaries, moderate filling of the smaller capillaries
Lower left Micropaque 40 % at + 37° C Complete filling only as far as the afferent arterioles
Lower right Micropaque 40 % at + 20° C Complete filling only as far as the interlobular arteries

Table are presented in Fig 3 Chromopaque has also other characteristics it can be more easily detected in the histologic specimen with all the usual staining methods (Fig 4) and it leads to better radiographic contrast

The degree of vascular filling varied in kidneys which were deep-frozen, stored and rewarmed to $+20^{\circ}\text{C}$, and then infused with Chromopaque 10 % There was complete filling of the afferent arteries but moderate or sparse filling of the smaller vessels No filling of the efferent arterioles could be detected

Discussion

The best way to fill the vessels to demonstrate the capillary level is to keep the temperature of the kidney and the contrast medium within physiologic limits This can be achieved when the animal is anesthetized and dies during the infusion Furthermore, the relative viscosity of the contrast medium should be about the same as that of the blood of the living animal One would think that under such conditions some kind of trauma or shock would alter the vascular pattern of the kidney (BARCLAY 1951) but no such phenomenon was observed, and all the vessels as far as the efferent arterioles were in fact filled with the contrast medium

The investigation indicates that the demonstration of vessels of a certain diameter may be achieved by choosing a suitable viscosity (HARRISON & HOEY 1960) of the contrast medium to be infused (see Table) The addition of gelatine has the advantage of making the medium thicken in the vessels so that it does not leak out during the fixation of the organ (RUBIN 1964) Gelatine can however not be used at temperatures lower than $+37^{\circ}\text{C}$ because of its coagulation tendency, at this temperature however and in low concentrations of the contrast medium, the addition of gelatine seems to produce good filling of the capillaries

No filling of the venous side was seen in this study This may be due to the fact that the solvent diffuses out of the capillaries and causes the contrast medium to be more concentrated, filling of the venous side cannot then occur For the opposite reason it is possible to obtain good contrast with a lower concentration in the smaller vessels

Comparison of the two contrast media discloses that Chromopaque has the advantage of producing a better radiographic contrast and in histologic sections can be seen more easily than Micropaque Contrast infusion for purposes of microangiography are often performed on deep-frozen stored material The present results indicate however that the filling of the capillaries is then not so good as when the material is fresh

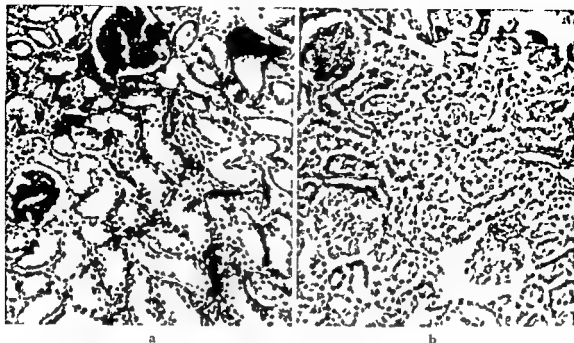


Fig 4 Histologic details from two renal capillaries in the rabbit completely filled with contrast media Van Gieson stain Reproduced from the original $\times 100$ a) Chromopaque 10% at $+37^{\circ}\text{C}$ The filling at the capillary level is clearly visible even in the histologic section b) Micropaque 10% at $+37^{\circ}\text{C}$ Poor contrast filling

Results

The results are presented in the Table The relative viscosity values at different temperatures and concentrations of the two contrast media are given in Fig 1 The relative viscosity of the blood was 4.8 at 20°C and 3.8 at 37°C

As the Table indicates, complete filling at the capillary level could be obtained when the viscosity of the contrast medium was the same or less than the viscosity of the blood When the viscosity was increased, the smaller vessels were not filled However, better filling was obtained at $+37^{\circ}\text{C}$ as compared to $+20^{\circ}\text{C}$, although at these temperatures the viscosity values are quite close to each other (exception Chromopaque 40%) The addition of 3% gelatine does not impair the filling of vessels if the relative viscosity of the contrast medium remains under 10 Examples of different grades of filling are given in Fig 2 In none of the specimens could any filling of the venous side be seen

The microradiograms indicated that the best filling to the capillary level was obtained at $+37^{\circ}\text{C}$ both with Micropaque 10% and Chromopaque 10% suspensions with or without gelatine 3% Examples of the criteria used for the

ATYPICAL ROENTGEN APPEARANCES OF THE LUNG IN HYALINE MEMBRANE DISEASE OF THE NEWBORN

by

ULF RUDHE, FREDERICK R. MARGOLIN and BENGT ROBERTSON

Diffuse symmetric pulmonary reticulogranularity has received considerable emphasis in roentgenologic descriptions of hyaline membrane disease of the neonatal lung. The atypical roentgen features of this disease have been only briefly mentioned (SCHULTZE 1958, CURRARINO & SILVERMAN 1957, AVERY 1968, PETERSON & PENDLETON 1955, and SINGLETON 1967). Little attention appears to have been given to the unevenly distributed or asymmetric pulmonary infiltrates seen in chest roentgenograms, especially during the first few hours of life.

We have reviewed the chest roentgenograms of 66 newborns in whom a clinical or pathologic diagnosis of hyaline membrane disease was made during the period 1959—1967 and demonstrated atypical roentgen features in twelve; post mortem examination was performed in eight of these infants who died within 144 hours post partum. (No histologic data were available for the four survivors.)

Fifty five additional infants with classical diffuse symmetric pulmonary reticulogranularity (Fig. 1) were chosen to represent the typical roentgenographic manifestations of hyaline membrane disease. The histologic specimens available

Submitted for publication 7 January 1969

Acknowledgements

This investigation was supported by the P O Klingendahl Foundation for Radiologic Research and by the Sigrid Juselius Foundation

SUMMARY

Two contrast media Micropaque and Chromopaque used in microangiography were studied in order to determine the effect of the temperature and concentration on the filling of the renal vasculature in the adult rabbit. Complete capillary contrast filling was obtained only when the concentration of the medium was 10 % and the infusion was made at $+37^{\circ}\text{C}$ when the anesthetized animal died during the procedure. Chromopaque appeared to be more satisfactory generally than Micropaque.

ZUSAMMENFASSUNG

Zwei Kontrastmittel Micropaque und Chromopaque die für Mikroangiographie angewendet werden wurden geprüft um den Einfluss von Temperatur und Konzentration auf die Darstellung der Nierengefäße der erwachsenen Kaninchen zu studieren. Komplette Kapillarfüllung wurde nur bei einer 10 %igen Konzentration des Kontrastmittels erreicht wenn die Infusion bei einer Temperatur von 37°C stattfand und das anesthetisierte Tier während des Experimentes starb. Chromopaque scheint im allgemeinen befriedigender als Micropaque zu sein.

RÉSUMÉ

Deux moyens de contraste Micropaque et Chromopaque utilisés en microangiographie ont été étudiés pour déterminer l'effet de la température et de leur concentration sur l'injection des vaisseaux rénaux du lapin adulte. On n'obtient une injection capillaire complète que quand la concentration de ces moyens de contraste est de 10 % quand l'injection est faite à 37°C et quand l'animal anesthésié meurt au cours de l'injection. D'une façon générale le Chromopaque parut plus satisfaisant que le Micropaque.

REFERENCES

- BARCLAY A E. Microarteriography Blackwell Publications Oxford 1951
 BELLMAN S. Microangiography Acta radiol (1953) Suppl No 107
 BULL H. An introduction to physical biochemistry F A Davis Company Philadelphia 1964
 HARRISON R G and HOLY M J. The adrenal circulation Blackwell Scientific Publications Oxford 1960
 HERZOG W. Zur Mikroangiographie Fortschr Röntgenstr 86 (1957) 124
 KORMANO M. Technical aspects in microangiography using barium sulfate (Micropaque) suspension Invest Radiol 2 (1967) 14
 LJUNGQVIST A. The intrarenal arterial pattern in the normal and diseased human kidney Acta med scand (1963) Suppl No 401
 — and LAGERGRÉN C. Normal intrarenal arterial pattern in adult and ageing human kidney J Anat (Lond) 96 (1962) 285
 RUBIN P. Microangiography facts and artifacts Radiol Clin N Amer 2 (1964) 499



Fig 2 Massive atelectases of reticulogranular type in right lower lobe and delicate disseminated atelectases in the remainder of the lungs in 1 day old infant who was a survivor of the respiratory distress syndrome

cases. The reticulogranularity was nevertheless diffuse in the roentgenograms. Evenly distributed atelectases throughout the lungs were revealed histologically in all the cases.

Intra alveolar edema, interstitial and intra alveolar hemorrhage and inflammation were seen in one or more lobes in twenty one of the twenty-three cases. The intensity of these changes was assessed according to the criteria given by ROBERTSON (1963). Severe hemorrhage (grade III) was encountered only among subjects living 3 to 5 days, while grades 0, I, and II occurred from the age of 1 to 2 days, and exceptionally at 5 to 6 days. Inflammation was observed in six cases only, four of which had grade I, one grade II and one grade III.

No lesion could be differentiated in the roentgenograms which presented evidence of typical diffuse bilateral atelectases of a reticulogranular type, except in one instance of grade III inflammation. The latter, which initially had the classical roentgen appearances of hyaline membrane disease, presented a distorted pattern compatible with complicating pneumonia on a second roentgen examination. It was also noteworthy that one of the cases with associated grade III hemorrhage involving all lobes had a characteristic diffuse reticulogranular pattern in the lung in serial films; these included post mortem roentgenograms. It appears that histologically massive pulmonary hemorrhage may be less likely to alter the characteristic reticulogranular pattern of hyaline membrane disease than inflammation of comparable severity.

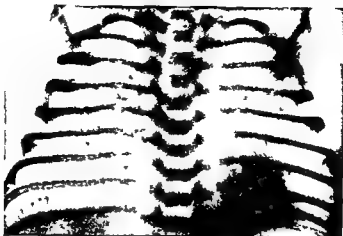


Fig 1 Typical roentgen features with regularly disseminated atelectases of reticulogranular type in a premature infant with hyaline membrane disease. Hyaline membranes and diffuse atelectases were present post mortem in all lobes of the lungs

in thirty-three of these served as controls for a comparison of the roentgenologic and histologic findings with the atypical cases under review

Methods Post-mortem histologic examination of the lungs was carried out in the eight fatal cases with 'atypical roentgenologic features, as well as in the thirty-three fatal cases of the control series. Specimens from all lobes were examined in six of the eight atypical cases and in twenty-three of the thirty three controls. Only 4 sections from different lobes were available in two atypical cases, and from 1 to 4 sections were studied in ten control cases.

Large frontal sections of the whole lungs were examined in a few instances. This greatly facilitated the spatial correlation of the roentgenologic and histologic findings (see Fig 5).

Results

Control series All the thirty-three cases of roentgenographically classical diffuse bilateral pulmonary reticulogranularity were proved to have hyaline membrane disease on histologic examination of the lungs. Hyaline membranes were uniformly distributed throughout the lungs in eighteen of the twenty-three cases in whom specimens from all lobes were available. A discrepancy between the roentgenologic and histologic findings was noted in five cases. Hyaline membranes were absent in one lobe, i.e. respectively the right upper, the left upper and the left lower lobe in three of these, and in the right middle lobe in the two remaining



Fig 2 Massive atelectases of reticulogranular type in right lower lobe and delicate disseminated atelectases in the remainder of the lungs in 1-day-old infant who was a survivor of the respiratory distress syndrome

cases. The reticulogranularity was nevertheless diffuse in the roentgenograms. Evenly distributed atelectases throughout the lungs were revealed histologically in all the cases.

Intra alveolar edema, interstitial and intra alveolar hemorrhage and inflammation were seen in one or more lobes in twenty one of the twenty three cases. The intensity of these changes was assessed according to the criteria given by ROBERTSON (1963). Severe hemorrhage (grade III) was encountered only among subjects living 3 to 5 days, while grades 0, I, and II occurred from the age of 1 to 2 days and exceptionally at 5 to 6 days. Inflammation was observed in six cases only, four of which had grade I, one grade II and one grade III.

No lesion could be differentiated in the roentgenograms which presented evidence of typical diffuse bilateral atelectases of a reticulogranular type, except in one instance of grade III inflammation. The latter, which initially had the classical roentgen appearances of hyaline membrane disease, presented a distorted pattern compatible with complicating pneumonia on a second roentgen examination. It was also noteworthy that one of the cases with associated grade III hemorrhage involving all lobes had a characteristic diffuse reticulogranular pattern in the lung in serial films, these included post mortem roentgenograms. It appears that histologically massive pulmonary hemorrhage may be less likely to alter the characteristic reticulogranular pattern of hyaline membrane disease than inflammation of comparable severity.

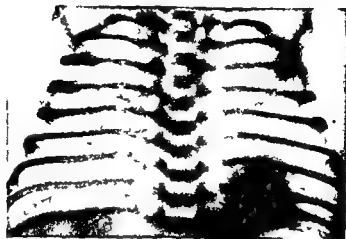


Fig. 1 Typical roentgen features with regularly disseminated atelectases of reticulogranular type in a premature infant with hyaline membrane disease. Hyaline membranes and diffuse atelectases were present post mortem in all lobes of the lungs.

in thirty-three of these served as controls for a comparison of the roentgenologic and histologic findings with the atypical cases under review.

Methods. Post-mortem histologic examination of the lungs was carried out in the eight fatal cases with 'atypical' roentgenologic features, as well as in the thirty-three fatal cases of the control series. Specimens from all lobes were examined in six of the eight atypical cases and in twenty-three of the thirty-three controls. Only 4 sections from different lobes were available in two atypical cases, and from 1 to 4 sections were studied in ten control cases.

Large frontal sections of the whole lungs were examined in a few instances. This greatly facilitated the spatial correlation of the roentgenologic and histologic findings (see Fig. 5).

Results

Control series. All the thirty-three cases of roentgenographically classical diffuse bilateral pulmonary reticulogranularity were proved to have hyaline membrane disease on histologic examination of the lungs. Hyaline membranes were uniformly distributed throughout the lungs in eighteen of the twenty-three cases in whom specimens from all lobes were available. A discrepancy between the roentgenologic and histologic findings was noted in five cases. Hyaline membranes were absent in one lobe, i.e. respectively the right upper, the left upper and the left lower lobe in three of these, and in the right middle lobe in the two remaining

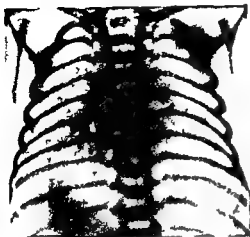


Fig 4 Reticulogranularity most accentuated in the central portions of the lungs and

central alveolar edema and hemorrhage

being more prominent in the lower lobes in three additional cases. Diffuse distribution of hyaline membranes was present in the remaining two cases of this group.

Irregularly distributed areas of intra alveolar and interstitial hemorrhage were noted, sometimes associated with intra alveolar edema in five of these eight cases. Edema alone was found in one child. Pneumonia was recorded in four and was the dominant microscopic finding in two of them. The time of appearance of the pneumonia could not be assessed. Signs of aspiration were inappreciable.

Pulmonary reticulogranularity was common to all the twelve atypical cases, although it was asymmetric and irregularly distributed. The changes predominated unilaterally in several cases and in the three survivors disproportionately involved one lobe (Fig 2).

The distribution of atelectases was roentgenographically more diffuse but spared the upper lobes (Fig 3) or the right middle lobe; this correlated with the histologic sections that demonstrated these lobes to be free of membranes. Another characteristic was the predominantly central distribution of reticulogranularity, leaving the peripheral parts of the lungs uninvolved on one or both sides (Fig 4).

The degree of intra alveolar or interstitial hemorrhage observed at autopsy in five instances ranged from grade I to grade II in four cases and was grade III in the remaining case. Since lesions of comparable degree of severity failed to alter the roentgenographic characteristics of generalized hyaline membrane disease in the control series, it was concluded that hemorrhage did not contribute significantly to the production of an asymmetric reticulogranular pattern.

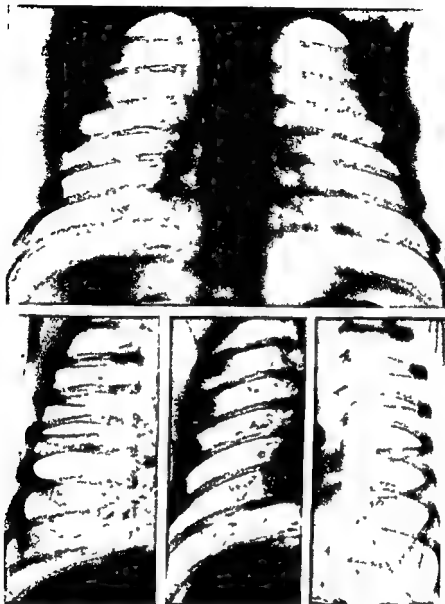


Fig 3 Typical reticulogranular pattern of diffuse atelectases in lower and middle lobes normal findings in the upper lobes in 1 day old infant progressive clinical deterioration and death at 3 days Histologic examination hyaline membranes in lower and right middle lobe none in upper lobes complicating moderate to marked intra alveolar hemorrhage and inflammation in upper and middle lobes (not visible in the 1 day roentgenogram)

Atypical disease Among the eight cases with roentgenologically atypical disease, one or two lobes were free of hyaline membranes on histologic examination in three instances. Membranes were present in all lobes, but unequally distributed,

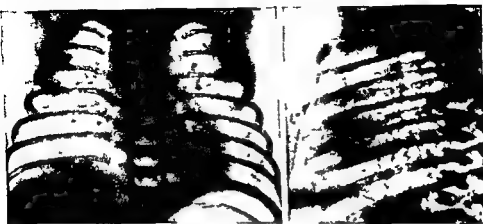


Fig 6 Scattered small infiltrates in both lungs interspersed with generalized reticulogranularity in 1-day-old infant. Histologic examination: hyaline membranes of varying thickness in all lobes, complicating widespread areas of pneumonia.

Variations in the typical appearances of the disease in one or more roentgenograms obtained in the course of the syndrome were noted in twelve cases. This retrospective study did not permit of a sufficiently close correlation of the histologic findings with the maximal asymmetry of the roentgenologic changes. Nevertheless, the evidence suggests that these atypical roentgen findings in the neonatal lung sometimes reflect the existence of a non generalized form of the disease, in which membranes are absent in one or more lobes. Atypical roentgen appearances may also result from the association of inflammation with the hyaline membrane lesion. By contrast, edema and hemorrhage, even when severe, do not seem to modify the classic roentgenologic features of the disease.

BLYSTAD *et coll* (1951) reported a series of 94 necropsies in infants with hyaline membranes who died between 1 hour and 5 days of age and in whom an associated pneumonia occurred in 29.1% and pulmonary hemorrhage in 45%. LANDING (1957), in a statistical study of 125 consecutive neonatal necropsies, found a definite association between pulmonary hemorrhage and pneumonia. He stated, however, that hyaline membranes were not significantly associated with either of these lesions. According to POTTER (1952), inflammation was usually noted in the lungs of infants with hyaline membrane disease who died after 48 hours. ROBERTSON (1963), in a histologic study of the relationship between pulmonary hyaline membranes and co-existing pulmonary lesions in the immediate neonatal period, reported that the incidence of complicating pneumonia and hemorrhage increased with postnatal age. Significant co-existing

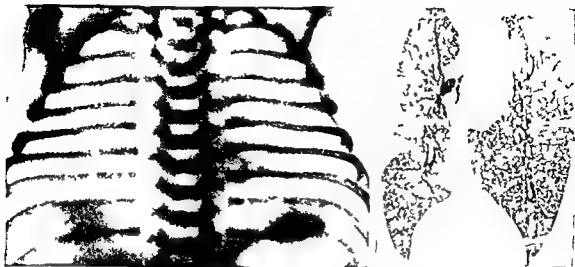


Fig 5 Disseminated atelectases of reticulogranular type and areas of consolidation in the lower lobes, particularly the posterobasal segments which project through the diaphragm in 1 day old infant who died at 11 days. Histologic examination: hyaline membranes present in all lobes accentuated in the lower lobes. Intra alveolar hemorrhage at apex of left upper lobe and pneumonic consolidation of parts of lower lobes. The frontal sections through the lungs show disseminated atelectases and areas of hemorrhage and pneumonia.

Post-mortem evidence of pneumonia, assessed as grade III, was noted in four instances, and was of lobar distribution in two cases (Fig 5). Multiple abscesses were scattered throughout the lungs of an additional newborn with sepsis and diabetic embryopathy (Fig 6).

An initially asymmetric and uneven distribution of reticulogranularity progressed to a more typically diffuse and symmetric appearance in three cases (Fig 7). An asymmetric parenchymal process persisted or progressed as a result of sepsis and lung abscesses in one of these.

Discussion

Collapsed alveoli, acrated terminal bronchioles, alveolar ducts, and hyaline membranes are typical microscopic findings in the lungs of infants dying of the respiratory distress syndrome. ROSENCREN (1967) has demonstrated in animal experiments that it is this histologic pattern that produces the reticulogranularity which radiographically is so characteristic of this disease. Since it is apparent that reticulogranularity relates to atelectases rather than to the membranes themselves this fact may explain why the diffuse atelectases and non-generalized membranes that were observed in five cases in the control series still had reticulogranularity throughout the lungs.

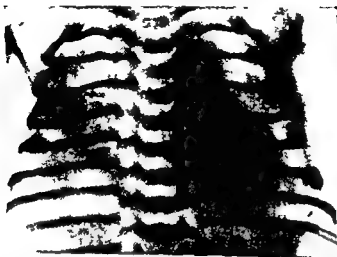


Fig 8 Almost airless lungs with loss of structural details at 36 hours. Histologic examination shows signs of massive intra uterine aspiration with areas of hyaline membranes in process of formation, multiple small interstitial hemorrhages

with the aspiration syndrome were examined at necropsy but in only one instance were hyaline membranes found. SINGLETON (1967) has referred to the relatively frequent occurrence of hyaline membranes in the lungs of infants who die of the aspiration syndrome. AVERY (1968), however, regarded this combination of findings as

pathologic. In contrast, whereas the aspiration syndrome is more prevalent in the postmature infant. However, aspiration atelectases, when present, may mask the reticulogranularity characteristic of hyaline membrane disease. This is particularly evident with massive aspiration when the thorax may be non-aerated, simulating the changes of severe hyaline membrane disease (Fig 8). As ROSEN-GREN (1967) stated, the reticulogranular pattern depends on at least partial alveolar aeration. Thus, reliable roentgenologic differentiation between these two processes is not possible in airless lungs.

The unilateral or predominantly lobar distribution of hyaline membrane disease has not been widely appreciated. MOLZ (1967) reported a case of hyaline membranes involving only one lung. Isolated lobar distribution of hyaline membranes was noted at necropsy in five cases with typical roentgen changes and in four of the cases with atypical roentgen findings in the present study, roentgeno-

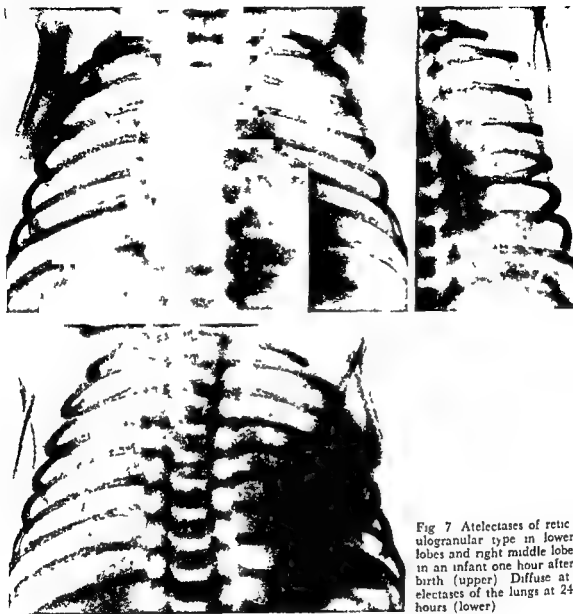


Fig 7 Atelectases of reticulogranular type in lower lobes and right middle lobe in an infant one hour after birth (upper) Diffuse atelectases of the lungs at 24 hours (lower)

pulmonary lesions, such as pneumonia or hemorrhage, were demonstrated histologically in one or several lobes of the lungs in six of the roentgenologically atypical, and in twenty-one of the control cases, in the present material

PETERSON & PENDLETON (1955) analyzed 104 neonatal roentgenograms that revealed a diffuse reticular pattern in the lungs and an additional 34 films with a coarse, irregular texture of atelectasis. The former represented hyaline membrane disease and the latter the aspiration syndrome, only in one case were the roentgen features of both diseases combined. The lungs in four of their cases

of the twenty three control cases was insufficient to produce a perceptible roentgenographic alteration in the reticulogranular pattern or it occurred preterminally and was not recorded in the last film obtained

Signs of aspiration were not observed Concurrent pneumothorax and resolution of the hyaline membrane process are conditions which should be considered when evaluating atypical reticulogranularity in the neonatal chest roentgenogram

Acknowledgement

Financial support from the Swedish National Association against Heart and Lung Disease is gratefully acknowledged This study was conducted when F R M., Research Fellow in Diagnostic Radiology National Institutes of Health U S A was on leave from the Department of Radiology, University of California School of Medicine San Francisco

SUMMARY

The atypical roentgenologic appearances of the lungs of 12 neonates with the respiratory distress syndrome are analyzed and in 8 of them compared with the results of histologic examination The roentgen features appear to reflect the findings that hyaline membrane disease may have a lobar distribution and may be complicated by significant pulmonary inflammation Difficulties and limitations of the roentgenologic evaluation are considered

ZUSAMMENFASSUNG

Atypische rontgenologische Lungenveränderungen bei 12 Neugeborenen mit schweren Atmungsstörungen werden besprochen und die Röntgenbefunde in acht von diesen Kindern werden mit den histologischen Erscheinungen verglichen Die Röntgenbefunde indizieren dass das hyaline Membran Syndrom mit einer lobaren Verteilung verbunden und durch Lungenentzündung kompliziert werden kann Die Schwierigkeiten und die Begrenzungen der rontgenologischen Diagnose werden diskutiert

RÉSUMÉ

Les auteurs décrivent les aspects radiologiques atypiques des poumons de 12 nouveaux nés atteints de syndrome de détresse respiratoire et les comparent dans 8 de ces cas avec les résultats de l'examen histologique Les signes radiologiques paraissent correspondre au fait que la maladie de la membrane hyaline peut avoir une distribution lobaire et peut être compliquée par une importante inflammation pulmonaire Ils examinent les difficultés et les limites du diagnostic radiologique

REFERENCES

- AVERY M E The lung and its disorders in the newborn infant W B Saunders, Philadelphia 1968
 — Comments to the special treatment in Progress in pediatric radiology ■ 135 S Karger, Basel and New York 1967

grams (Fig. 3) in atypical cases with lobes free of membranes were easily recognized.

Neonatal pulmonary reticulogranularity either unevenly distributed or admixed with coarse atelectases should suggest the presence of combined disease and the possibility of a significant complicating disorder, inflammatory conditions should in particular be considered.

Asymmetry and irregularity of distribution of reticulogranular pulmonary infiltration must be interpreted cautiously. An apparent unilateral decrease in reticulogranularity may reflect the presence of a small pneumothorax on that side. PETERSON & PENNINGTON stated that a pneumothorax usually accentuates the reticulogranular pattern. This is true when the volume of pleural air is relatively large and the lung has collapsed to the maximum of its markedly reduced compliance. With a small pneumothorax, the air collected anteriorly in the supine infant will spuriously diminish the contrast of the lung structures. Interstitial pulmonary emphysema preceding the development of a pneumothorax may cause sufficient bronchiolar and parenchymal compression to produce a reticulogranular pattern. This however is usually of a coarse type and not to be confused with the delicate pattern observed in hyaline membrane disease.

When the hyaline membrane process undergoes regression, an uneven pattern of resolution may occur. Roentgen examination of the lungs may reveal an asymmetric and irregular distribution of reticulogranularity (RUDHE & BROBERGER 1967) which should not be misinterpreted as complicating or intercurrent disease, serial examination should serve to exclude this possibility.

Conclusions

Asymmetric, non-homogeneous reticulogranularity characterized the chest roentgenograms of eight neonates with histologically proven hyaline membrane disease. These were roentgenographically considered atypical compared with thirty-three cases displaying characteristic, homogeneous reticulogranularity and in which the lung tissue was also available for study.

Pulmonary lobes free of hyaline membranes were present in three of the eight atypical and in five of the twenty-three typical cases. In the former group, these lobes were obviously free of disease roentgenographically. In the latter group, however, diffuse atelectases throughout the lobes uninvolved by membrane formation produced roentgen features indistinguishable from adjacent lobes containing hyaline membranes.

Irregularly distributed reticulogranularity in the remaining atypical cases probably reflected the presence of complicating inflammatory change, while interstitial and intra-alveolar hemorrhage present in four of these and in twenty one

RESIDUAL CONTRAST MEDIUM IN THE INTESTINES AND SIDE EFFECTS DURING CHOLECYSTOGRAPHY

A comparison between some contrast media in current use
and a new medium

by

SVEN ERIKSSON and GEORG-FREDRIK SALTZMAN

Oral cholecystography must today be regarded as one of our most reliable
methods for . . .

the passage through the bile ducts is unobstructed. For two reasons,
however, we have continued the search for better preparations. Some of the
contrast substances have caused unpleasant side effects such as nausea, sometimes
with vomiting, diarrhoea, and other reactions, and a few do not become com-
pletely reabsorbed, a considerable residue still being demonstrable in the in-
testines 12 hours after administration. The present paper describes an inves-
tigation to compare four of the contrast media most widely used for cholecysto-
graphy, and a new preparation that promises to be a valuable and technically
advantageous addition to our diagnostic aids. The main aspects studied were the

- BLYSTAD W, LANDING B H and SMITH C A : Pulmonary hyaline membranes in newborn infants, statistical, morphologic and experimental study of their nature, occurrence and significance *Pediatrics* 19 (1951), 5
- CURRARINO G and SILVERMAN F N : Roentgen diagnosis of pulmonary disease of the newborn infants *Pediatr Clin N Amer* 4 (1957), 27
- LANDING B H : Pulmonary lesions of newborn infants, a statistical study *Pediatrics* 19 (1957), 217
- MOLZ G : Einseitiges Vorkommen alveolärer Hyaliner Membranen bei einem unter der Geburt verstorbenen Neugeborenen *Helv paediat Acta* 22 (1967), 5
- PETERSON JR H G and PENDLETON M E : Contrasting roentgenographic pulmonary patterns of hyaline membrane and fetal aspiration syndromes *Amer J Roentgenol* 74 (1955), 800
- POTTER E : Pathology of the fetus and the newborn Year Book Publisher, Chicago 1952
- ROBERTSON B : The relationship between hyaline membranes of the newborn and the presence of other pulmonary lesions *Acta paediat (Uppsala)* 52 (1963), 569
- ROSENGREN K : Hyaline membrane disease A radiological investigation in rabbits *Acta radiol* (1967) Suppl No 262
- RUDHE U and BROBERGER U : Roentgenologic observations in survivors of clinical hyaline membrane disease of the newborn *Ann Radiol* 10 (1967), 230
- SCHULTZE G : Chest film findings in neonatal respiratory distress *Radiology* 70 (1958), 230
- SINGLETON E B : Respiratory distress syndrome *In* : Progress in pediatric radiology Vol 1, p 135 S Karger, Basel and New York 1967

separated by a 12 hour interval HEALEY & GRAINGER reported nausea in 15 % of their cases BOGATZKI (1959), KEINER (1959), MULLER & SIELAFF (1959), GOERKE (1960), and STENHOUSE (1962) all found a low incidence of complications, a point of interest is that MULLER & SIELAFF had given 6 g in a single dose CRECELIUS among 100 cases observed nausea in six and diarrhoea in one case after a dose of 3 g

Present investigation A comparative study on a uniform series of cases has been performed A series of 100 cholecystographies without evidence of pathologic changes, taken in succession without selection, was studied for each of four contrast media in current use, Telepaque, Bilijodon Natrium, Osbil, and Biloptin The administration of the substance and the roentgenographic technique were identical in every instance, the amount of contrast medium given was 3 g With few exceptions, all the patients were living in Stockholm at the time of the examination, and it is thus unlikely that differences in water affected the results

The investigation also included a series (100 cases) of cholecystographies without evidence of pathologic changes, in which the patients had received a new contrast medium, which at present goes under the working name of A 1579 This was also given in a dose of 3 g The radiopaque component of this preparation is the sodium salt of iopanoic acid, in other words the same as in Bilijodon-Natrium, the mode of preparation is however different

The resorption of an orally administered drug is often related to its solubility in water The dissolving rate of a preparation increases if its specific surface is increased, i.e. if its particle size is reduced Small particles may be obtained by mechanical micronizing or by precipitation under certain special conditions Both these methods have been tried with iopanoic acid, which in itself is not easily soluble Mechanical micronizing did not produce sufficiently small particles however and the particles obtained by precipitation proved to have low stability, they showed a tendency to rapid crystallization and to coalesce into larger aggregates

Another way to encourage resorption is to prepare salts easily soluble in water When mixed with sour gastric juice the iopanoic acid is precipitated in the form of fine particles which, in theory, ought to be readily dispersible in gastric and intestinal juices Iopanoic acid, however, after precipitation of for instance its sodium salt, aggregates into large clumps which hinder its resorption These clumps are noticeably coarser than those that occur after administration of the acid as such Thus, neither of these two methods proved suitable

One way of preventing aggregation of the contrast medium in the gastric juice is to add a surface active constituent, which preferably should lack disturbing pharmacologic effects The surface active agents previously used, such as

presence of residual contrast medium in the intestines, and the occurrence of side effects

Among established contrast media, Telepaque (Winthrop), Biliiodon-Natrium (Leo), Osbil (Byk-Gulden), and Biloptin (Schering), officially described as iopanoic acid, the sodium salt of iopanoic acid, the sodium salt of iobenzamic acid, and the sodium salt of iopodoic acid, respectively, were selected for study

Several authors have reported a residue in the intestines with the first two preparations although the frequency figures differ widely For Telepaque, incidences ranging from 50 to 100 % of all examinations have been mentioned, and an even greater divergence is reported for Biliiodon-Natrium, the figures varying from under 10 % to 90 % ANDRÉN & THFANDER (1960) have attempted to explain these large variations They have demonstrated that residual material is more often observed in the intestines when the whole abdomen is investigated (90 %) than when a conventional examination taking in the gall-bladder region alone is performed (60 %) They stated that the variations in some cases might be explained by varying degrees in the hardness of the drinking water, in other words that different drinking waters, when combined with the contrast medium, might to a varying extent form salts that dissolve slowly and are not readily absorbed A study of the literature suggests that Biliiodon-Natrium leaves a smaller residue than Telepaque, although no such difference was observed by ANDRÉN & THFANDER

The frequency of residual material after the use of Biloptin is considered low It has been stated in general that no disturbing precipitation of contrast medium into the intestines occurs if the dose is kept at 3 g (CRECELIUS 1959, GOERKE 1960, WILBRAND 1961, HEALEY & GRAINGER 1965) Not even with 6 g, given in two doses of 3 g each, separated by an interval of 12 hours, did WHITESIDE obtain any residue MULLER & SIELAFF (1959) however noted a considerable residue in the colon in films taken 5 hours after the administration of 6 g in a single dose

Side reactions have been reported to be common with both Telepaque and Biliiodon-Natrium According to PETERHOFF (1956) and others, a dose of 3 g causes nausea or diarrhoea in roughly a third of all cases HEALEY & GRAINGER mentioned a much higher frequency for Telepaque, however The incidence seems to be proportional to the size of the dose, and approximately the same for both preparations

The reports on side effects from Biloptin also vary Whereas WHITESIDE (1960) and MURRAY (1962) noted nausea, in some cases with vomiting, diarrhoea and headache, in over half of their cases, SALTZMAN (1960) observed no reactions at all among his first 45 cases WHITESIDE and MURRAY had however given their patients a double dose (6 g) divided into two doses of equal size,

A 1579 were asked to reply to the simple question "Did you experience any discomfort after swallowing the medicine?" No attempts were made to draw any information on subtle and consequently uncertain reactions

The incidence of side effects from these three preparations, with 100 cases tested in each group, was for Osbil and for Biloquin 3% (five cases of nausea and one case of diarrhoea in each), and for A 1579 it was 11% (ten cases of nausea and one case of diarrhoea)

None of these preparations produced any appreciable reactions. Compared with the incidence of side effects after Telepaque and Biliogon-Natrium (30 to 35% formerly reported), that recorded for Biloquin, Osbil and A 1579 may be said to be low. These three preparations thus seem to be in a class on their own among those at present available for oral examination of the biliary tract. A 1579

number of cases of nausea, another study was carried out in a new series of 100 cholecystographies in which the patients were given dragées made in a machine. Only three patients in this series complained of nausea although eight patients had diarrhoea. The side effects thus remained unchanged in the total frequency but seemed to have altered in character.

Residual contrast medium in the intestines was observed in five patients in whom the machine-made dragées were used.

Telepaque, Biliogon-Natrium, Osbil and Biloquin are well-established contrast media with well known cholecystographic properties. As no reports on A 1579 are as yet available there seems to be justification for giving a brief account of experience in clinical trials with this preparation.

The contrast density of A 1579 is good, and fully equal to that obtained with other contrast media. The authors have investigated 46 cases in which pathologic changes appeared to be present. No contrast filling of the gallbladder was obtained in fourteen of the cases, half of which were operated upon. Pathologic changes that could well have been the explanation of the absence of filling of the gallbladder were present in every instance. The incidence of residual contrast medium in the intestine as well as of side effects was the same as in the normal cases.

Conclusions

Considerable differences were observed between the contrast media investigated in this study. From the aspects of the residue left in the intestines and the side

Tween 80 and peanut oil, have had an appreciably contractive effect on the gallbladder, however, and attempts to find a suitable agent were therefore directed towards those without a fatty acid component likely to have this effect

The surface active agent that best fulfilled these requirements was a non-ionic active polyol, this is a condensation product of propylene oxide and propylene glycol. Polyol is a substance that is solid at room temperature and virtually tasteless and odourless. It is soluble in water, stable to acids and alkalis and is not precipitated by metal ions, it is not metabolized in the body and has an acute oral toxicity expressed as LD₅₀ of 15 g/kg rat. A preparation of equal parts of the sodium salt of iopanoic acid and the aforementioned surface active agent forms in artificial gastric juice (0.2 g NaCl and 1.5 g 5 M HCl in 100 ml water, pH 1.2 to 1.5) an extremely finely dispersed suspension with particles smaller than 1 μ . There is no sign of crystal formation after an hour.

Results

Residual contrast medium The incidence of residual contrast medium demonstrated in the intestines after the administration of the different substances was as follows, the total number of cases in each group being 100

	Per cent cases with residue
Telepaque	74
Bilijodon-Natrium	60
Osbil	22
Biloptin	5
A 1579	3

This comparison reveals a fundamental difference between Telepaque and Bilijodon-Natrium on the one hand and Biloptin and A 1579 on the other. A small difference is apparent between Telepaque and Bilijodon-Natrium, the incidence of residual contrast medium being slightly higher for Telepaque although on the other hand the residue was extremely fine-grained. The residue from Bilijodon-Natrium is coarser, a fact that sometimes causes difficulties in the interpretation of films of the gallbladder region. Osbil occupies an intermediate position, the residue varies in appearance when this preparation is used but seldom causes diagnostic problems.

Side effects These were recorded systematically only for Osbil, Biloptin and A 1579. As regards Telepaque and Bilijodon-Natrium, their side reactions are so well known and the reports in the literature are so unanimous that further systematic study seemed unnecessary. All patients who received Osbil, Biloptin or

- CRECELIUS G A Beitrag zur Methodik der peroralen Darstellung der Gallenblase und der grossen Gallenwege Berl Med 10 (1959) 443
- FLEISCHMANN E und WANKE G Erfahrung mit Osbil, einem neuen oralen Gallenkontrastmittel Wien med Wschr 103 (1961), 1964
- GIDES H Zur peroralen Cholezysto-Cholangiographie mit dem neuen Röntgenkontrastmittel Osbil Fortschr Med 80 (1962), 275
- GOERKE H Perorale Cholezystangiographie durch zweiseitiger Applikation von Biloptin Berl Med 11 (1960) 72
- GOLLMAN G HAMMER H und UNGER E Das Problem des objektiven Nachweises der Verträglichkeit eines Gallenkontrastmittels Wien klin Wschr 73 (1961), 347
- HEALEY T and GRAINGER R C A clinical trial of oral cholecystographic media Telepaque, Biloptin, Osbil tablets and Osbil capsules Brit J Radiol 38 (1965), 57
- HELFFERICH K H Ergebnisse und Erfahrungen mit einem neuen Gallenblasenkontrastmittel (Osbil) und einem Kontraktionsmittel in trockner Form Med Welt 38 (1962), 2011
- KEINER F Die orale Cholezystographie und Cholangiographie mit Biloptin Medizinische 51 (1959) 2530
- MURRAY J P Clinical trial of Biloptin in oral cholecystography Brit. J Radiol 35 (1962), 278
- MÜLLER W und SIELAFF H J Über die Möglichkeit peroraler Gallengangdarstellung mit Biloptin Medizinische 51 (1959) 2528
- PETERHOFF R Cholecystography with the sodium salt of iopanoic acid Acta radiol 46 (1956) 719
- RAVELLI R Osbil, ein neues perorales Gallenkontrastmittel Wien klin Wschr 74 (1962), 133
- SALTZMAN G F Solu Biloptin as a contrast medium for peroral cholegraphy Acta radiol. 54 (1960) 417
- SCHLAGER K und SCHUSTER H Osbil ein neues orales Gallenkontrastmittel Wien klin Wschr 74 (1962) 28
- STENHOUSE D Oral cholecystography by Biloptin Brit J Radiol 35 (1962), 637
- WHITE W W and FISCHER H W A double blind study of Oragrafin and Telepaque Amer J Roentgenol 87 (1962) 745
- WHITEIDE C G Biloptin A new oral contrast medium for cholecystography Brit J Radiol 33 (1960) 124
- WILBRAND H F Cholecystografi med Biloptin (In Swedish) Sv Lakartidn 58 (1961), 1078

reactions, Biloptin, Osbil and A 1579 today appear to be the preparations of choice for cholecystography.

Biloptin and Osbil on the one hand and A 1579 on the other represent different lines of development in the work for improved contrast media. Two preparations, Biloptin and Osbil, which are definitely superior to those previously in use, have emerged in the trials of new chemical compounds. It must be pointed out that the active substance in A 1579 is identical with that in Bilijodon-Natrium, i.e. the sodium salt of iopanoic acid, but a new mode of preparation has led to improved results.

SUMMARY

Four well-established contrast media for oral cholecystography, Telepaque, Bilijodon-Natrium, Osbil, and Biloptin, and a new preparation, A 1579, have been studied from the aspects of residues in the intestine and side reactions. Biloptin, Osbil, and A 1579 appear to be better than the others. A comparison between the side effects from hand-made and machine-made dragées of the A 1579 preparation suggested that there might be some connection between the coating and the nature of the side effects.

ZUSAMMENFASSUNG

Vier gewöhnliche Kontrastmittel für Cholezystographie, Telepaque, Bilijodon-Natrium, Osbil und Biloptin, sowie ein neues Kontrastmittel, A 1579, wurden in Hinsicht auf den Rückstand im Darm und die Nebenreaktionen überprüft. Biloptin, Osbil und A 1579 scheinen in dieser Hinsicht besser als die anderen Kontrastmittel zu sein. Ein Vergleich der Nebenwirkungen von bzw. bei Hand und maschinell verfertigten A 1579-Dragées deutete darauf hin, dass ein Zusammenhang zwischen den Nebenwirkungen und der Art des Dragée Überzuges bestehe.

RÉSUMÉ

Les auteurs ont étudié les résidus intestinaux et les effets secondaires de quatre moyens de contraste bien connus pour la cholécystographie orale, Telepaque, Bilijodon-Natrium, Osbil, et Biloptin, et un nouveau produit, A 1579. Le Biloptin, l'Osbil et le A 1579 paraissent supérieurs aux autres produits. La comparaison entre les effets secondaires de dragées de A 1579 faites à la main et des dragées faites à la machine fait penser qu'il peut y avoir un certain rapport entre l'enrobage des dragées et la nature des effets secondaires.

REFERENCES

- ANDRÉN L and THEANDER G. Residual contrast medium in the bowel in cholecystography with iopanoic acid and certain related substances. *Acta radiol* 53 (1960), 371.
BOGATZKI M. Perorale, fraktionierte Cholezysto- und Cholangiographie. *Fortschr Röntgenstr* 91 (1959), 729.

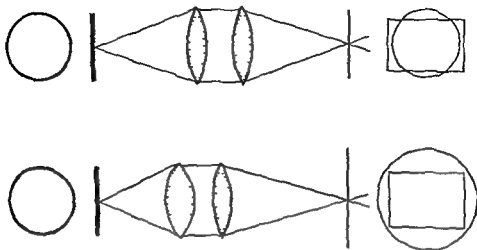


Fig 1 Path of rays in a conventional twin lens system (top) A magnification of the projected image obtained with the method described (below) Output screen to the left and film frame to the right

able conditions for small objects but were not sufficiently satisfactory for the special examinations now considered. Tests with available standard equipments failed to produce satisfactory results and it was therefore necessary to modify the system.

Direct magnification techniques utilizing roentgen tubes with subnormal focal size (0.3 mm) may be possible but if high speed recording is required, the highest

Another connecting image intensifier and cinecamera. This was done. It is common experience that when a relatively small object is presented with a large screen intensifier the result is unsatisfactory, a fact that has led to the introduction of electronic magnification. The richness of image details available, especially in the centre of the output screen, makes optical magnification possible. It may be mentioned that for other purposes a magnification of the output phosphor image to 70 mm film size and over may be achieved with good result.

In the conventional cineroentgenographic system the projection of the output screen is such that it utilizes the full surface of the film frame optimally. This is a compromise between size of image and magnification. For the 35 mm cinecameras this system is usually constructed according to the twin or tandem lens principle with 'equal area framing' (Holm 1968), the image of the output screen being projected in the same size on the 35 mm cinefilm frame. This

CINEROENTGEN EQUIPMENT FOR SMALL OBJECTS

by

OVE MATSSON

The daily routine of a roentgen department often includes motility studies of small objects in the human body in which the study of detail is of importance. Most image intensifiers have so large an input screen that the conditions for small objects are unfavourable. The equipment now described would appear to constitute a solution of the problem and has given excellent results in clinical studies.

Extremity surgery often demands motility studies of certain joints with cine-roentgenography. Studies of function are necessary, in particular for assessing the therapeutic aspects and the results of treatment of the joints of wrists and hands.

Many intensifier tubes offer a possibility of direct electronic magnification to obtain an improved image of small objects. This refinement is ordinarily available only in medium-sized or large tubes, the magnified image corresponding to a surface which is 5 inches (about 125 mm) in diameter compared with the normal 9 inches (about 230 mm). The gain obtained is, however, due to electronic factors, accompanied by reduced intensification.

Furthermore, an input surface reduced to 5 inches in place of the ordinary 9 inches offers no more than the early intensifiers with an input screen of 5 inches. The latter, which are now practically out of production, provided more favour-



Fig 3 Two rad ographic frames from a motion study of the wrist

is limited by the aperture of the smaller of the lenses, the light output compared with that from a conventional twin lens system is reduced. This means that the exposure must be increased, which is no disadvantage. The effect of quantum mottle may be critical when employing magnification, however, if too small amounts of radiation are used. The actual exposure increase is moderate but contributes to better detail identification.

The apparatus has been used at speeds up to about 50 frames a second. The focussing and adjustment of the object is easily made through the reflex viewfinder system of the camera connected to the lens system, and the cine-roentgenographic recording can be followed continuously. An increased camera speed should preferably be used, as the magnification makes motion blur practically unavoidable. Pulsing may prove advantageous.

A study of the wrist in two frames as presented in Fig 3. The apparatus has also been used with success in studies of small changes in the oesophagus during deglutition and for the examination of the vocal cords.

SUMMARY

The optical system of an image intensifier-cinecamera combination may be changed to increase the central part of the output screen image so that more favourable conditions for the study of small objects are obtained. The method is of special value in the study of function and the dynamic conditions of joints.

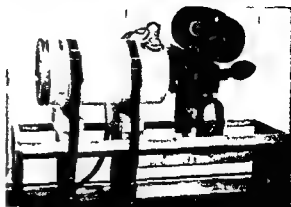


Fig 2 Apparatus for cinerentgenographic studies especially of small objects. A 5 inch intensifier has been equipped with a modified lens system to give a more favourable recording scale on the cinefilm frame

method is usually well suited for conventional image intensifiers, the size of the projected image being suitable for the frame and constituting a compromise between its scale and detail size and the amount of detail lost outside the borders of the frame. The conditions correspond to what is illustrated in Fig 1 (top), where the lens system is built up symmetrically. As the objects considered fill up only the centre of the image field, a modification is introduced which allows the output phosphor image to be projected onto the film frame with the central part magnified, in other words with a 'blowing-up' of the central part of the image.

The modification has been achieved in the following manner. A conventional 35 mm Arriflex camera for professional movie use was combined with an ordinary 5-inch Philips intensifier, and a special modified lens system was introduced between the output phosphor image and the film frame. The combination of two anastigmatic lenses, one of comparatively small and the other of greater focal length may produce the desired effect (Fig 1). The linear magnification compared with a symmetrical twin lens system can then be expressed for arbitrary values of focal length as $M = f_1/f_2$.

In the equipment presently used (Fig 2), anastigmatic lenses with focal lengths of 35 and 50 mm, as well as 28 and 50 mm, were employed. Enlargements of about 40 % and 80 %, respectively, may be obtained. The method was developed after experiments with both 16 mm and 35 mm systems and with various lenses.

It should be pointed out that there is often a certain vignetting effect in connection with most image intensifiers and the definition of the peripheral parts of the image, excluded in this technique, are often reduced in definition as well as underexposed. By reduction of the primary radiation at the centre of the input screen all unnecessary radiation may also be screened off, which is of advantage for the image contrast.

Because of the magnification and the fact that the diameter of the light beam

ANGIOGRAPHY IN INTRACRANIAL CAVERNOUS HEMANGIOMAS

by

HLOO BOOREN, CHRISTIAN SYLANDER and INGVAR WICKBOM

Only a few reports have appeared in the literature dealing with the radiologic findings in cases of intracranial cavernous hemangioma. We have not been able to find any report of a proved case with angiographic changes typical or suggestive of the condition. The angiographic findings in four proved and one possible case of intracranial cavernous hemangioma are now presented. Four of the cases were intracerebral and one extracerebral.

Case reports

Case 1 (Fig. 1). A male who was 36 years old when first examined in 1953. He had then had frontoparietal headache for 5 years and occasional attacks of blurred vision. No abnormality was found at angiography (only 3 films at about 2-second intervals had been obtained) or at encephalography, apart from moderate widening of the anterior horns.

In 1961 the patient was re-admitted because of his first grand mal seizure. Electroencephalography disclosed a focal abnormality in the right frontotemporal region, which had been present in 1956 but not in 1953. Encephalography revealed a subfrontal mass on the right side (Fig. 1a). At carotid angiography (Fig. 1b) of the same side, an unusually wide vein ran from the anterior part of the cingular gyrus above the corpus callosum around

From Roentgen -

ZUSAMMENFASSUNG

Man kann das optische System einer Kombination von Bildverstärker und Cinecamera derartig modifizieren, dass man durch Vergrößerung des Zentrums des Schirmbildes eine bessere Beobachtung von kleinen Objekten erhält. Die Methode ist von besonderem Wert bei Funktionsstudien der Gelenke.

RÉSUMÉ

Il est possible de modifier le système optique d'un ensemble intensificateur d'image cine camera pour agrandir la partie centrale de l'image de l'écran de sortie pour étudier dans des conditions plus favorables de petits objets. Cette méthode a un intérêt particulier dans l'étude de la fonction et des conditions dynamiques des articulations.

REFERENCES

- HOLM TH / Proposed practice for cinefluorographic framing. Abstract from a paper read at the 4th Symposium Cineradiographicum in Nice, June 1968. X ray Bulletin 11 (1968) 18
- ÖNNE L. Personal communication

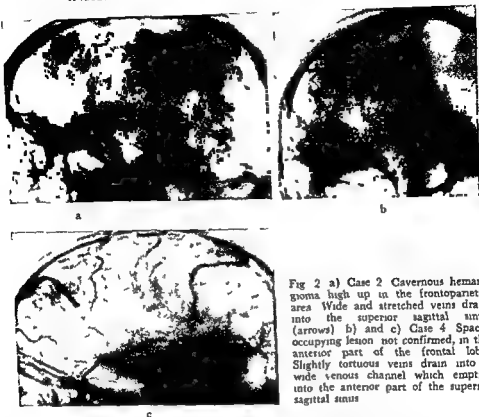


Fig 2 a) Case 2 Cavernous hemangioma high up in the frontoparietal area Wide and stretched veins drain into the superior sagittal sinus (arrows) b) and c) Case 4 Space occupying lesion not confirmed, in the anterior part of the frontal lobe Slightly tortuous veins drain into a wide venous channel which empties into the anterior part of the superior sagittal sinus

cerebral arteries appeared normal Microscopically the mass was found to be composed of thin walled blood spaces, varying in size and closely packed in the central part but partly separated by gliotic brain tissue towards the periphery There was no capsule Thrombosis of varying age was present in some of the blood spaces but most of them were patent Residues from earlier haemorrhages with phagocytes loaded with iron containing pigment were seen The tumour had no resemblance to hemangioendothelioma or glioma

Case 2 (Fig 2a) Male, aged 35, with a history of rapidly progressing weakness of the left arm and leg ending in spastic hemiplegia He had also had vertigo and severe headache for some time Right side central abnormality was recorded at electroencephalography Right side carotid angiography revealed a space-occupying lesion high up in the frontoparietal region displacing the vessels in an arched manner No tumour vessels were present but the veins draining that area filled early and remained filled a little longer than other veins

At operation, a hematoma was evacuated and at autopsy a few days later microscopy revealed structures of a cavernous hemangioma in the margin of the cavity In addition, there was another small cavernous hemangioma in the left occipital lobe (left side angiography had not been performed)

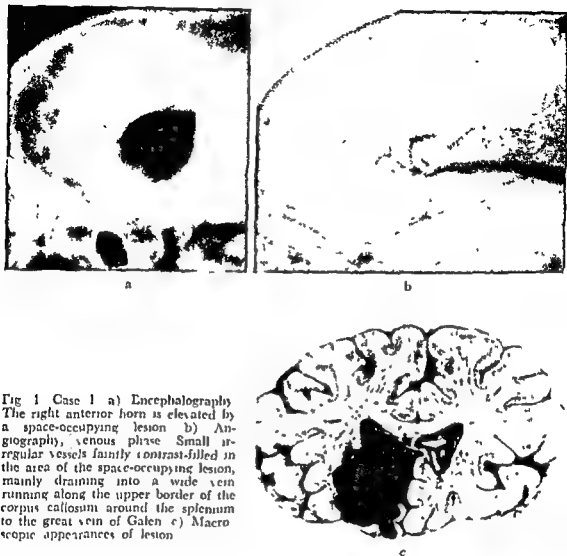


Fig 1 Case 1 a) Encephalography. The right anterior horn is elevated by a space-occupying lesion b) Angiography, venous phase. Small irregular vessels faintly contrast-filled in the area of the space-occupying lesion, mainly draining into a wide vein running along the upper border of the corpus callosum around the splenium to the great vein of Galen c) Macroscopic appearances of lesion

the splenium, to empty into the vein of Galen. No abnormal vessels could be detected in the routine series of films (with 6 films at 1-second intervals). However, a repeat series with more films during the venous phase revealed irregular faintly filled vessels in the area of the subfrontal mass emptying into the wide vein. The vein appeared at about the same time as other cerebral veins but remained filled for a longer time. A less wide vein from the same area emptied into the sphenoparietal sinus. There was no obvious displacement of vessels. When reviewing the angiographies from 1953 the large vein could be seen but was only faintly contrast-filled and appeared less wide. The patient refused operation.

Encephalography and angiography were repeated in 1964 with the same findings as in 1961.

At the end of 1966 the patient died in a status epilepticus, at autopsy a mass was found medially in the right frontal lobe. The tumour was fairly well circumscribed, dark brown in colour, and 2.5 cm in diameter. The vascularization in the vicinity was not increased. The



Fig 4 Astrocytoma grade II in the anterior part of the frontal lobe. A number of veins draining the tumour empty into the internal cerebral vein.

sinus was displaced downwards and incompletely filled. Some wide veins were seen just anterior to this. Left external carotid angiography revealed no abnormality.

An extracerebral tumour not infiltrating the sinus was removed at operation. The histologic diagnosis was that of cavernous hemangioma. Since operation the patient has been free of symptoms.

Discussion

Pathologic features Cavernous angiomas of the brain and meninges are considered as extremely rare vascular malformations or hamartomas (POOL & POTTS 1965). They are not true neoplasms but may appear malignant in some respects, e.g. they sometimes increase in size. The relationship to capillary telangiectasis has been a matter of dispute. Some authors regard the cavernous angioma as a stage of evolution from the telangiectasis (RUSSELL 1931) and term both telangiectases (WILBUR & MASON 1943). This is not accepted by others. The lack of conformity in terminology no doubt makes it difficult to compare the different data published, even more so since sometimes no clear definition nor any description of the histologic appearances of a lesion are included.

Cavernous angiomas have certain morphologic characteristics distinguishing them from other types of angiomatous malformations in the brain. Microscopically they should be well delimited, but usually not encapsulated, and composed of closely packed vascular channels, often wide but with considerable variation in size. The blood spaces are thin-walled, with single endothelium, and should at



Fig 3 Case 5 Veins displaced in the region of the defect, just anterior to which lies a wide, irregular, densely filled vein

Case 3 Female, aged 18, was admitted because of grand mal seizure, preceded by severe frontal headache. Electroencephalography recorded a right-side frontotemporal focus. The vessels at angiography were seen to be displaced around an area of about 3 cm diameter in the frontal pole. No abnormal vessels were seen. Veins in the area filled and emptied in about the same time as other veins. The lesion was removed and was at microscopy found to be a cavernous hemangioma.

Case 4 (Fig 2, b and c) Male, aged 45, was admitted because of right-side grand mal seizures and frontal headache. He had had one seizure 21 years prior to admission but had otherwise been healthy. Electroencephalography showed no definite abnormality.

At carotid angiography on the left side a wide vein was seen in the right frontal lobe, right side angiography was then performed. Small tortuous vessels were seen in the anterior part of the frontal lobe in the late arterial and early venous phase within a rounded area of about 2 cm diameter. The vessels drained into a wide vein leading to the superior sagittal sinus. This vein was filled about one second before the other veins on the convexity and remained so for a longer time.

Angiography was repeated 6 weeks later with the same findings. Bilateral angiography repeated again 9 months later produced the same appearances.

Encephalography has been performed on three occasions and each time the right ventricle failed to fill with air. The patient's condition is now, two and a half years after the first examination, about the same. Operation has so far not been performed, partly because the angiographic changes have suggested a hemangioma rather than a true neoplasm.

Case 5 (Fig 3) Male, aged 56, who during the previous 6 years had had attacks of headache lasting from a few hours to a few days. During the same time he had noticed a tender spot in the parietal region close to the midline, and in the last year a tender fluctuating tumour had developed in the same area. A polycyclic bony defect, with a diameter of 3 to 4 cm, corresponding to the lump, was observed at skull examination. At left internal carotid angiography the small arteries in this area were displaced from the vault and the sagittal

graphy, but the diagnosis was not confirmed. The same is true about Case 2 of the two cases of intra-orbital cavernous hemangiomas, reported by DILENCE et coll (1965). Judging from the illustration this lesion appears more compatible with an arteriovenous malformation than a cavernoma. In their Case 1, which was confirmed although the histologic findings were not mentioned, they described the mass as becoming opaque although this is hardly evident from their illustrations.

The non filling of cavernous hemangiomas has been ascribed to the fact that few vessels in general enter the formation (SCHEIDER & LISS 1958). ROBINSON et coll (1966) stated that the cavernous hemangioma, in contrast to the arteriovenous malformation, usually lacks large afferent vascular channels and its internal circulation is therefore frequently sluggish.

No feeding arteries could be demonstrated at angiography in the present cases. The irregular and faintly filled veins seen in Cases 1 and 4 may represent some of the cavernous vascular channels in the lesion but are probably only draining veins. The small veins in Case 1 were not obvious without a rapid serial technique and a larger amount of contrast medium. The most striking angiographic feature consisted of large draining veins in all cases except maybe Case 3. In two cases (Cases 2 and 4) they filled early and in two cases (Cases 1 and 4) remained filled for a longer time than other veins. During the arterial phase the cavernomas appeared only as avascular masses.

In disagreement with these findings RUSSELL & RUBINSTEIN (1963) failed to identify enlarged draining veins from cavernous hemangiomas at autopsy, but they may of course be overlooked if collapsed. BLACKWOOD (1941) on the other hand found enlarged draining veins from capillary telangiectases at autopsy. Angiographic appearances of the kind demonstrated in the present cases are, however, not pathognomonic, as evident from the case illustrated in Fig 5. In this case, the wide veins draining the tumour area and emptying into the internal cerebral vein were similar to those demonstrated in the present cases of cavernous hemangioma, they filled a little later than the other cerebral veins but remained filled for a longer time. The diagnosis suggested by microscopy was grade II astrocytoma.

Angiographic findings similar to those in cavernous hemangiomas have been described in cases of Sturge Weber's disease (GREEN & ARANA 1948, WAPPEN-SCHMIDT 1967), but the clinical entity in this condition is usually typical and characteristic calcifications are usually present.

CURTIS (1949) in an unverified case described a slow accumulation of contrast medium in the angioma followed by an equally slow venous drainage.

The reason why the angioma itself does not fill out may be due to a small calibre of the feeding arteries and a slow circulation, or extensive thrombosis, or



Fig 5 Angiography of a cavernous hemangioma in the thigh Arterial (a) and venous phase (b) after arterial injection and after direct injection into the angioma (c) Only part of the lesion is demonstrated after arterial injection

least in the central part not be separated by cellular substance. Signs of thrombosis, haemorrhages of different age, as well as organisation, sometimes with calcification may occur (RUSSELL & RUBINSTEIN 1963). Four of the present cases had histologic characteristics in conformity with this description. Case 2 is an example of a small cavernous angioma, associated with intracerebral haematoma. It is evident that the hemangioma causing a haematoma may easily be overlooked unless careful microscopic examination is performed.

Angiographic appearances We have not been able to find any report in the literature of a proved case of cavernous hemangioma in the brain demonstrated at angiography. Previously reported cases have been described at angiography or encephalography only as expanding lesions (FURTADO et coll 1951 one case, SCHNEIDER & LISS 1958 three cases with angiography performed in one case, JAIN 1966 one case of intraventricular cavernous hemangioma with calcifications, ISHIIJMA et coll 1966 two cases, one of which was examined with carotid angiography). In KAMRIN & BUCHSBAUM's (1965) two confirmed cases and in the case published by ROBINSON et coll (1966) nothing abnormal was recorded at angiography. CURTIS (1949) on the other hand reported a case of what he thought to be an intracerebral cavernous hemangioma, contrast-filled at angio-

graphy, but the diagnosis was not confirmed. The same is true about Case 2 of the two cases of intra-orbital cavernous hemangiomas, reported by DILLON et coll (1965). Judging from the illustration this lesion appears more compatible with an arteriovenous malformation than a cavernoma. In their Case 1, which was confirmed although the histologic findings were not mentioned, they described the mass as becoming opaque although this is hardly evident from their illustrations.

The non filling of cavernous hemangiomas has been ascribed to the fact that few vessels in general enter the formation (SCHNEIDER & LISS 1958). ROBINSON et coll (1966) stated that the cavernous hemangioma, in contrast to the arteriovenous malformation, usually lacks large afferent vascular channels and its internal circulation is therefore frequently sluggish.

No feeding arteries could be demonstrated at angiography in the present cases. The irregular and faintly filled veins seen in Cases 1 and 4 may represent some of the cavernous vascular channels in the lesion but are probably only draining veins. The small veins in Case 1 were not obvious without a rapid serial technique and a larger amount of contrast medium. The most striking angiographic feature consisted of large draining veins in all cases except maybe Case 3. In two cases (Cases 2 and 4) they filled early and in two cases (Cases 1 and 4) remained filled for a longer time than other veins. During the arterial phase the cavernomas appeared only as avascular masses.

In disagreement with these findings RUSSELL & RUBINSTEIN (1963) failed to identify enlarged draining veins from cavernous hemangiomas at autopsy, but they may of course be overlooked if collapsed. BLACKWOOD (1941) on the other hand found enlarged draining veins from capillary telangiectases at autopsy. Angiographic appearances of the kind demonstrated in the present cases are, however, not pathognomonic as evident from the case illustrated in Fig. 5. In this case, the wide veins draining the tumour area and emptying into the internal cerebral vein were similar to those demonstrated in the present cases of cavernous hemangioma, they filled a little later than the other cerebral veins but remained filled for a longer time. The diagnosis suggested by microscopy was grade II astrocytoma.

Angiographic findings similar to those in cavernous hemangiomas have been described in cases of Sturge Weber's disease (GREEN & ARANA 1948, WAPPEN-SCHWIDT 1967), but the clinical entity in this condition is usually typical and characteristic calcifications are usually present.

CURTIS (1949) in an unverified case described a slow accumulation of contrast medium in the angioma followed by an equally slow venous drainage.

The reason why the angioma itself does not fill out may be due to a small calibre of the feeding arteries and a slow circulation, or extensive thrombosis, or

a combination of both BARTLEY & WICKBOM (1959) in their examination of soft tissue cavernous or venous hemangiomas sometimes observed wide vascular channels or lakes that filled in the late phase and remained outlined for a considerable time. They could however not always be demonstrated after intraarterial injection but only after introduction of the medium directly into the lesion.

In a case of cavernous hemangioma of the thigh examined in our department only part of the lesion was filled after arterial injection, injection directly into the hemangioma produced however filling of wide vascular channels. The non-filling in this case may accordingly not be attributed to thrombosis within the angioma. Nor was extensive thrombosis seen in any of the cases of intracranial cavernomas. The findings thus seem to support the view of SCHNEIDER & LISS (1958) and ROBINSON et coll (1966) that cavernous hemangiomas lack large afferent vessels.

The series is small but there would appear to be justification in diagnosing a cavernous hemangioma angiographically if wide veins seem to drain a space-occupying lesion, apparently poor vascularization of the latter and prolonged contrast-filling of the veins support the diagnosis.

SUMMARY

Four proved and one unconfirmed case of intracranial cavernous hemangioma examined with carotid angiography are reported. Wide draining veins in some cases contrast filled for a fairly long time were demonstrated in spite of the fact that no abnormal vessels could be defined in the lesion itself. The significance of the angiographic findings is discussed.

ZUSAMMENFASSUNG

Es wird über vier Fälle von bestätigtem und einem Fall von unbestätigtem cavernösen Haemangiom des Schädels berichtet. Alle Fälle waren mittels Carotisangiographie untersucht. In allen Fällen zeigten sich weite und ziemlich andauernd gefüllte Abflussvenen obwohl keine abnorme Gefäße im Tumor gesehen wurden. Die Bedeutung der angiographischen Befunde wird besprochen.

RÉSUMÉ

Présentation de quatre cas prouvés et d'un cas non confirmé d'hémangiome caverneux intracranien examinés par angiographie carotidienne. Il y avait de larges veines de drainage qui dans certains cas restaient opacifiées pendant un assez long temps bien que l'examen n'ait pas montré de vaisseaux anormaux dans la lésion elle-même. Les auteurs examinent l'intérêt des signes angiographiques.

REFERENCES

- BARTLEY O and WICKBOM I Angiography in soft tissue hemangiomas *Acta radiol* 51 (1959) 81
- BLACKWOOD W Two cases of benign cerebral telangiectasis *J Path Bact* 52 (1941), 209
- CASTAIGNE P, BUGE A, PERTUISSET II et coll Angiome thrombosé, radiologiquement exclu *Bull Soc Méd Paris* 77 (1961), 923
- CURTIS J B Rapid serial angiography preliminary report *J Neurol Neurosurg Psychiat* 12 (1949), 167
- DURENGE II, FISCHGOLD H et DAVID M L'angiographie par soustraction de l'artère ophtalmique et de ses branches Masson et Cie, Paris 1965
- FURTADO D, MARQUES V et CARVALHO O Angiome caveux du cerveau *Acta neurol belg* 51 (1951) 343
- GREEN J R and ARANA R Cerebral angiography *Amer J Roentgenol* 59 (1948), 617
- ISHIJIMA Y, MATSUMURA H and KAGEYAMA N Intracranial cavernous hemangioma report of two cases *Arch jap Chir* 30 (1966) 748
- JAIN K K Intraventricular cavernous haemangioma of the lateral ventricle *J Neurosurg* 24 (1966), 762
- KAMRIN R B and BUCHSBAUM H W Large vascular malformations of the brain not visualized by serial angiography *Arch Neurol (Chic)* 13 (1965), 413
- POOL J L and POTTS D G Aneurysms and arteriovenous anomalies of the brain Harper & Row New York 1965
- ROBINSON F, PORRO R S and SCATLIFT J H Angiographic recognition of occipital lobe infarction *Neurology* 16 (1966) 1016
- RUSSELL D Discussion on vascular tumours of the brain and spinal cord *Proc roy Soc Med* 24 (1931) 383
- and RUBINSTEIN L J Pathology of tumours of the nervous system Edward Arnold, London 1963
- SCHNEIDER R C and LEE L Cavernous hemangiomas of the cerebral hemispheres *J Neurosurg* 15 (1958), 392
- WAPPENSWHIFT J Das Arteriogramm und seine Bedeutung bei nicht kalkifiziertem Angioma capillare et venosum (Sturge Weber) *Acta neurochir* 16 (1967), 309
- WYBURN MASON R The vascular abnormalities and tumours of the spinal cord and its membranes Kimpton London 1943

FIBROMUSCULAR HYPERPLASIA OF THE CAROTID ARTERIES

by

POUL F. ANDERSEN

Since the rediscovery of fibromuscular hyperplasia of the renal arteries by WYLIE & WELLINGTON 1960, more intensified angiographic efforts to demonstrate corrigible causes of arterial hypertension have brought to light an increasing number of cases of extrarenal arterial dysplasia, a term proposed by HUNT et coll (1962), and HILL et coll (1965). During the period 1964—1966, PALUBINSKAS et coll and WILIF et coll (1966) have reported a number of cases with carotid systems having angiographic appearances typical of fibromuscular hyperplasia of the renal arteries. The first histologically verified case of fibromuscular hyperplasia of the carotid arteries, however, was published by CONNETT & LANSCH (1965).

This was followed in 1967 by a report of a case by EHRENFELD et coll, a case by RAINFORD et coll (1968) and three cases by MORRIS et coll (1968). These were mainly of young middle-aged women with signs of intermittent, transient cerebral ischemia and were often cured by resection of the stenosed area. The cases reported by other authors (e.g. WYLIE et coll 1966) also had a considerable female preponderance while the occurrence in children seems to be extremely rare (ANDERSEN, to be published).

The author during the past two years has had the opportunity of observing four cases of fibromuscular hyperplasia of the carotid arteries, one of which was in a



Fig 1 Case 1 Fibromuscular hyperplasia of the internal carotid artery below and above the carotid canal. Saccular aneurysm with typical spasm following hemorrhage.



Fig 2 Case 2 Typical 'string of beads' configuration of the external carotid artery, with slight post stenotic dilatation at the level of first and second cervical vertebrae.

male child and two in elderly women dying from rupture of cerebral saccular aneurysms, thus corroborating the hypothesis of WYLIE *et coll*. The cases were histologically verified and presented the typical microscopic appearances described in the literature (HUNT *et coll* 1962, HARRISON *et coll* 1967, MacDONALD & McMILLAN 1963, SUTTON *et coll* 1963, WYLIE *et coll* 1966). As both the female patients died from subarachnoid hemorrhage, the present paper may serve the purpose of calling attention to the possibility of intracranial aneurysms occurring in a high percentage of cases of fibromuscular hyperplasia. An at present asymptomatic case of fibromuscular hyperplasia in the external carotid artery is also reported.

Case reports

Case 1 A 54 year old woman was admitted after a weeks illness to a small general hospital on account of several episodes of unconsciousness and convulsions preceded by intense headache for about 15 minutes. She was said to have had a similar attack 4 years previously and on admittance was confused, drowsy and slightly hypertensive. There were no neurologic signs and a diagnosis of climacteric psychosis was made. The drowsiness increased however, central facial paresis and signs of a subarachnoid hemorrhage developed and the patient was transferred to us.

Carotid angiography by direct puncture disclosed a saccular aneurysm of the left anterior



Fig 3 Case 3 Fusiform aneurysm of right internal carotid artery dilatation and configuration typical of fibromuscular hyperplasia b) Lateral angiogram Saccular aneurysm of anterior cerebral artery

cerebral artery with typical spasm of the adjacent segments of the anterior and middle cerebral arteries (Fig 1). The external extracranial part of the internal carotid artery presented the string of beads appearance characteristic of fibromuscular hyperplasia. Six hours later the condition of the patient deteriorated rapidly with brain stem convulsions and fall of blood pressure and she died before anything could be done.

At autopsy a saccular aneurysm and subarachnoid hemorrhage were observed in the inferior region of the left frontal lobe in accord with the arteriographic findings. The extracranial part of the left internal carotid artery and the left renal artery presented evidence of slight corrugations of the intima. Atheromatosis of the aorta was the only other microscopic abnormality. Microscopy with hematoxylin eosin and elastin staining preparations of the distal part of the left internal carotid artery and the left renal artery revealed subintimal and medial fibrotic hyperplasia and fragmentation of the internal lamina elastica consistent with the criteria established by HURT et coll. and WALLACE et coll.

Case 2 A 69 year old man was admitted because of a history of cerebral circulatory insufficiency. He displayed slight transient expressive aphasia on examination but a neurosomatic investigation revealed no abnormality and no arterial hypertension. Ophthalmoscopy and gamma cencephalography were normal. EEG indicated periodic preponderance of low frequent activities in the left temporal region.

Carotid angiography was performed by low puncture of the left common carotid artery. No intracranial abnormality was present in the left anterior and middle cerebral arteries and their ramifications. The extracranial part of the internal carotid artery including the carotid bifurcation was not abnormal. The external carotid artery however from the origin of the main occipital artery and 3 cm distally was the site of a typical string of beads contour distinctly different from the standing waves which as reported by WICKBOM & BARTLEY (1957) often occur in the carotid arteries. The patient on account of the slight

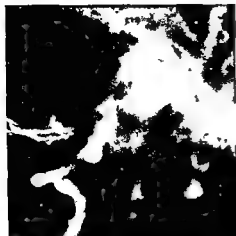


Fig 4 Case 4 *Left* Lateral angiogram Upper part of vertebral artery appears extensively corrugated *Right* Extensive lesions of the internal and external carotid arteries

and transient symptoms declined further examinations, thus, no histologic nor renal angiographic verification was obtained. He was discharged free of symptoms and has remained so for the past two years.

Case 3 A 48 year old woman was admitted because of vomiting, increasing confusion and somnolence after sudden headache. She was obese and was known to have had arterial hypertension for at least 10 years, with frequent spells of headache for a period of about 2 years. The cerebrospinal fluid was blood stained. EEG presented marked changes.

At carotid angiography a saccular aneurysm measuring about 10 mm \times 5 mm was seen on the anterior communicating artery, with a hematoma in the right frontal lobe. The patient's condition deteriorated rapidly into deep coma with right hemiparesis and marked arterial hypertension and she died before surgical intervention could be made. The angiographic findings were confirmed at autopsy. Sections disclosed typical plaques of subintimal fibrosis and a varying calibre of the internal carotid artery, some of the plaques contained cholesterol crystals.

Case 4 Boy, aged 8 years, represents a case that will be reported upon in detail in a subsequent paper (ANDERSEN). At the age of 2 years he was found to be suffering from endocardial fibro-elastosis. The prognosis was considered poor and no treatment was given. Attacks interpreted as psychomotor epilepsy started at the same age. Three years later a neurosomatic examination was normal and EEG had a spike focus over the left fronto-temporal area and bilateral synchronous spike paroxysms. The cardiac status was unchanged and the patient was placed on anti-epileptic medication. He was well at several controls, apart from having difficulty in running.

The admission at the age of 8 years was caused by an influenza like state that had started 12 days earlier with fever, disorientation, and meningeal reactions. Possible hemorrhage from a cerebral vascular malformation was suspected. Bilateral systolic bruits were present over the carotid arteries but not over the femoral arteries. EEG was grossly abnormal, with spike paroxysms over both temporal regions.

Bilateral carotid and vertebral angiography by direct puncture disclosed extensive lesions of the fibromuscular hyperplasia type in all areas. Cinephalography indicated moderate cortical atrophy in the insular regions. Nephro angiography revealed typical fibromuscular hyperplasia of both renal arteries. A similar condition was noted in the hepatic, inferior mesenteric and some of the lumbar arteries. Biopsy of the superficial temporal artery disclosed typical fibromuscular hyperplasia.

The patient is now on antiepileptic medication and without cerebral symptoms. His cardiac condition is controlled by digitalis and he is free from hypertension.

Discussion

The increasing number of cases of external fibromuscular hyperplasia reported during the past few years as well as the present cases indicate that the condition may affect any artery. It manifests itself according to the physiologic effects on the arterial territory by stenosing or disruptive changes in the vessel. As the stenotic process usually dominates, the ischemic symptoms are liable to prevail. The disruptive effect on the arterial wall of the splitting of the internal elastic membrane may however well be the explanation of the absence of hypertension in at least one third of all cases of renal fibromuscular hyperplasia (ANDERSEN 1966). Case 1, which resembles the cases reported by WALIR et coll (1966), had insignificant hypertension prior to the actual disease. This is in accord with the fact that the kidneys were macroscopically normal and the renal arteries without stenotic lesions. While the walls of the renal arteries were sites of fibromuscular hyperplasia the renal parenchyma was microscopically normal.

No hypertension was present in the remaining three cases. Cases 2 and 3 were not subjected to nephro angiography on account of the total absence of renal and hypertensive signs. The arteriographic appearances were however typical and constant and bore no resemblance to the 'stationary waves' reported, e.g. by BELBER & HOFFMAN (1968), RAINER et coll (1968), STEINBERG (1966) or WICKBOM & BARTLEY (1957). The presence of an intracranial aneurysm in Case 3 also strongly corroborated the radiologic diagnosis.

Contrary to the cases reported by other authors, e.g. MORRIS et coll (1968), the present Cases 1, 3 and 4 had typical angiographic fibromuscular hyperplasia changes in the intracranial part of the internal carotid arteries. Case 4 is especially remarkable on account of the extensive arterial lesions and the age of the patient. This is the first child reported with histologically verified carotid and vertebral lesions. The combination of endocardial fibroelastosis and fibromuscular hyper-

plasia is also interesting and suggests challenging hypotheses. The fact that the simultaneous occurrence of fibromuscular hyperplasia and endocardial fibro-elastosis had not previously been reported may perhaps be explained by the limited autopsies, interest being centered exclusively on the cardiac disease, the clinical signs of which in this age group (0 to 4 years) are impressive and tend to overshadow slight renal hypertension. Normal macroscopic appearances of the renal and other abdominal arteries in spite of incipient microscopic fibromuscular hyperplasia changes (as in Case 1) also adds to the possibility of the condition being overlooked.

No intracranial aneurysm could be demonstrated in Case 4 with vertebral artery involvement, as MORRIS *et coll* did in their case of possible vertebral fibromuscular hyperplasia. It must however be admitted that the changes in all the intracranial vessels were so marked that one or more of the bulges may well have represented a small aneurysm. The future course of this case will be interesting.

The preponderance of female cases of fibromuscular hyperplasia (85 per cent), as demonstrated e.g. by PALLINISKAS & NEWTON (1965), and the combination of the condition with intracranial aneurysm seem real and should be an indication for renal nephro angiography in all cases of subarachnoid hemorrhage, even if most occur in one isolated region, the American West coast. A thorough angiographic analysis of each case of this syndrome must add valuable information regarding etiologic factors.

SUMMARY

Four cases of fibromuscular hyperplasia of the carotid and vertebral arteries are reported. The significance of the increasing manifestation of the condition in other regions is discussed. Two of the cases are of females with an intracranial saccular aneurysm combined with fibromuscular hyperplasia. Hypertension is not a prominent feature of the condition.

ZUSAMMENFASSUNG

Es wird über vier Fälle mit fibromuskulärer Hyperplasie der Carotis und Vertebral arterien berichtet. Die Bedeutung der Ausbreitung dieser Erkrankung auf andere Körperregionen wird erörtert. Zwei Patientinnen hatten ausser der fibromuskulären Hyperplasie cerebrales sakkuläres Aneurysma. Hochdruck in diesen Fällen ist nicht hervorragend.

RÉSUMÉ

L'auteur présente quatre cas d'hyperplasie fibromusculaire des artères carotides et vertébrales. Il examine l'importance de l'aggravation des manifestations de cette affection dans d'autres régions. Deux de ces cas sont des femmes qui présentent un anévrisme sacculaire intracranien associé à une hyperplasie fibromusculaire. L'hypertension n'est pas un caractère important de cette affection.

REFERENCES

- ANDERSEN P. E. Fibromuscular hyperplasia. Paper read at the 27th Scandinavian Congress of Radiology Oslo 1966
- Fibromuscular hyperplasia in children. To be published in *Acta radiol.* Diagnosis
- BRIDGER C. J. and HOFFMAN R. B. The syndrome of intracranial aneurysm associated with fibromuscular hyperplasia of the renal arteries. *J Neurosurg* 28 (1968) 556
- CONNETT M. C. and LANGSHU J. M. Fibromuscular hyperplasia of the internal carotid artery. *Ann Surg* 162 (1965) 59
- FRIEDRICH W. K., STONEY R. J. and WYLIE E. J. Fibromuscular hyperplasia of the internal carotid artery. *Arch Surg* 95 (1967) 284
- HANSEN J., HOITEN C. and THORBERG J. V. Hypertension in two sisters caused by so called fibromuscular hyperplasia of the renal arteries. *Acta med scand* 178 (1965) 461
- HARRISON E. G., HUNT J. C. and BERNATZ P. E. Morphology of fibromuscular dysplasia of the renal artery in renovascular hypertension. *Amer J Med* 43 (1967) 97
- HILL L. D. and ANTONIUS J. I. Arterial dysplasia. *Arch Surg* 90 (1965) 585
- HUBER P. and FUCHS W. A. Gibt es eine fibromuskuläre Hyperplasie zerebraler Arterien? *Fortschr Röntgenstr* 107 (1967) 119
- HUNT J. C., HARRISON E. G., KINKAID O. W. et coll. Idiopathic fibrous and fibromuscular stenosis of the renal arteries associated with hypertension. *Proc Mayo Clin* 37 (1962) 181
- LEADERBETTER W. F. and BURLAND C. E. Hypertension in unilateral renal disease. *J Urol* 39 (1938) 611
- MACDONALD J. S. and McMILLAN J. A. Fibromuscular hyperplasia of the renal arteries. *Clin Radiol* 14 (1963) 392
- MORRIS G. C., LECHTER A. and DEBAKEY M. E. Surgical treatment of fibromuscular disease of the carotid arteries. *Arch Surg* 96 (1968) 636
- PALUBINSKAS A. J. and NEWTON T. H. Fibromuscular hyperplasia of the internal carotid arteries. *Radiol clin Biol* 34 (1965) 365
- and RIPLEY H. R. Fibromuscular hyperplasia in extrarenal arteries. *Radiology* 82 (1964) 451
- and WYLIE E. J. Roentgen diagnosis of fibromuscular hyperplasia of the renal artery. *Radiology* 76 (1961) 634
- PERLOFF D. and NEWTON T. H. Fibromuscular hyperplasia. *Amer J Roentgenol* 98 (1966) 907
- RAINER W. G., CRAVER G. G., NEWBY J. P. and CLARKE J. P. Fibromuscular hyperplasia of the carotid artery causing positional cerebral ischaemia. *Ann Surg* 167 (1968) 444
- STEINBERG I. Stationary waves of the superficial femoral arteries. *Amer J Roentgenol* 98 (1966) 901
- SUTTON D., BRUNTON F. J., FOOT E. C. and GUTHRIE J. Fibromuscular fibrous and non atheromatous renal artery stenosis and hypertension. *Clin Radiol* 14 (1963) 381
- WICKBOM I. and BARTLEY O. Arterial spasm in peripheral arteriography using the catheter method. *Acta radiol* 47 (1957) 433
- WYLIE E. J. and WELLINGTON J. S. Hypertension caused by fibromuscular hyperplasia of the renal artery. *Amer J Surg* 100 (1960) 183
- BINKLEY F. M. and PALUBINSKAS A. J. Extrarenal fibromuscular hyperplasia. *Amer J Surg* 112 (1966) 149

EMBOLIC COMPLICATIONS IN CEREBRAL ANGIOGRAPHY WITH THE CATHETER TECHNIQUE

by

S. CRONQVIST, H. O. ELSING and E. PALACIOS

Complications in angiography depend mainly upon the technique (SCHEINBERG & ZUCKER 1963, ALLEN et coll 1965, AMUNDSEN et coll 1963). The present contrast media probably play only a minor role (MARGOLIS et coll 1958, TONNIS & SCHIEFER 1959, LANG 1963).

The techniques in cerebral angiography consist of direct puncture and catheterization. Direct punctures of the carotid and the vertebral arteries have been most commonly used to date. These methods possess however obvious drawbacks. The difficulty in keeping a needle in position in vertebral angiography is well known (CRONQVIST 1961) and the same applies to carotid angiography. Subintimal or even extravasal injections of contrast medium are common (ALLEN et coll 1965). The development of an arteriovenous fistula following needle puncture has been reported (OLSON et coll 1963, LESTER 1966) and intracranial embolization has been described (RIMPAU & SEILS 1957, DECKER 1960, EIKEN & GORMSEN 1962, ZATZ & IANNOLE 1966). This may be due to dislodging of small clots formed within the needle or of tissue particles trapped in the lumen of the

Submitted for publication 21 March 1969

REFERENCES

- ANDERSEN P. E.: Fibromuscular hyperplasia. Paper read at the 27th Scandinavian Congress of Radiology, Oslo 1966
- Fibromuscular hyperplasia in children. To be published in *Acta radiol.* Diagnosis
- BELDER C. J. and HOFFMAN R. B.: The syndrome of intracranial aneurysm associated with fibromuscular hyperplasia of the renal arteries. *J. Neurosurg.* 28 (1968), 556
- CONNETT M. C. and LANSCH J. M.: Fibromuscular hyperplasia of the internal carotid artery. *Ann. Surg.* 162 (1965), 59
- ENRICH F. W. K., STONEY R. J. and WYLIE E. J.: Fibromuscular hyperplasia of the internal carotid artery. *Arch. Surg.* 95 (1967), 284
- HANSEN J., HOLTEN C. and THORBERG J. V.: Hypertension in two sisters caused by so called fibromuscular hyperplasia of the renal arteries. *Acta med. scand.* 178 (1965), 461
- HARRISON E. C., HUNT J. C. and BERNATZ P. F.: Morphology of fibromuscular dysplasia of the renal artery in renovascular hypertension. *Amer. J. Med.* 43 (1967), 97
- HILL L. D. and ANTONIUS J. I.: Arterial dysplasia. *Arch. Surg.* 90 (1965), 585
- HUBER P. and LUCHS W. A.: Gibt es eine fibromuskuläre Hyperplasie zerebraler Arterien? *Fortschr. Röntgenstr.* 107 (1967), 119
- HUNT J. C., HARRISON E. C., KINKADE O. W. et coll.: Idiopathic fibrous and fibromuscular stenosis of the renal arteries associated with hypertension. *Proc. Mayo Clin.* 37 (1962), 181
- ISADOREWITZ W. I. and BURKLAND C. F.: Hypertension in unilateral renal disease. *J. Urol.* 39 (1938), 611
- MACDONALD J. S. and McMICHAEL J. A.: Fibromuscular hyperplasia of the renal arteries. *Clin. Radiol.* 14 (1963), 392
- MORRIS G. C., ICHTER A. and DEBAKEY M. E.: Surgical treatment of fibromuscular disease of the carotid arteries. *Arch. Surg.* 96 (1968), 636
- PAUBINSKAS A. J. and NEWTON T. H.: Fibromuscular hyperplasia of the internal carotid arteries. *Radiol. clin. Biol.* 34 (1965), 365
- and RILEY H. R.: Fibromuscular hyperplasia in extrarenal arteries. *Radiology* 82 (1964), 451
- and WYLIE E. J.: Roentgen diagnosis of fibromuscular hyperplasia of the renal artery. *Radiology* 76 (1961), 634
- PERLOFF D. and NEWTON T. H.: Fibromuscular hyperplasia. *Amer. J. Roentgenol.* 98 (1966), 907
- RAINER W. G., CRAWFORD G. G., NEWBY J. P. and CLARKE J. P.: Fibromuscular hyperplasia of the carotid artery causing positional cerebral ischaemia. *Ann. Surg.* 167 (1968), 144
- STEINBERG I.: Stationary waves of the superficial femoral arteries. *Amer. J. Roentgenol.* 98 (1966), 901
- SUTTON D., BRUNTON F. J., FOOT E. C. and GUTHRIE J.: Fibromuscular fibrous and non atherosclerotic renal artery stenosis and hypertension. *Clin. Radiol.* 14 (1963), 381
- WICKBOM I. and BARTLEY O.: Arterial 'spasm' in peripheral arteriography using the catheter method. *Acta radiol.* 17 (1957), 433
- WYLIE E. J. and WELLINGTON J. S.: Hypertension caused by fibromuscular hyperplasia of the renal artery. *Amer. J. Surg.* 100 (1960), 183
- BINKLEY F. M. and PAUBINSKAS A. J.: Extrarenal fibromuscular hyperplasia. *Amer. J. Surg.* 112 (1966), 119



Fig 1 Case 2 Small filling defect at the division of one of the Sylvian vessels (a) The patient developed transitory neurological signs. One week later, entirely normal angiography (b)

before the examination proceeds. The wire guide is thoroughly cleaned between each procedure.

Case reports

Case 1 Woman, aged 53, with signs of subarachnoid haemorrhage starting 3 weeks before admission. Angiography with catheterization of the right and left carotid arteries was normal. The catheter was then once again placed in the right carotid artery for further films. The speech of the patient was impaired in connection with the injection of contrast medium. Now a 2 mm long filling defect, not previously present, was observed in one of the Sylvian vessels; the passage of the contrast medium through the partially occluded vessel was exceptionally slow. The clinical signs were transitory and complete recovery occurred within minutes.

Case 2 Man, aged 46, with headache (Fig 1). Ophthalmoneurologic examination on admission revealed papillary stasis and encephalography demonstrated a suprasellar tumour. Bilateral carotid angiography with catheterization from the femoral artery was performed. The right angiogram was normal. The left carotid artery was then catheterized and contrast material was injected. Five minutes later the patient complained that he could not move the fingers of the right hand; some minutes later his speech was impaired. The symptoms gradually disappeared. Angiography then disclosed an embolus at the bifurcation of one of the Sylvian arteries.

Case 3 Boy, aged 10 years, was brought to the hospital with left-sided seizures and conjugated deviation of the eyes to the right side. EEG showed a focus on the right side. Right

needle when penetrating the soft tissue. Mobilized thrombotic material from a punctured atheromatous plaque is also thought to cause embolization, and emboli formed by foreign substances, such as cotton fibres, have been described (ADAMS et coll. 1965).

The catheter technique was first introduced by ICHIKAWA (1938) and FARIÑAS (1941) and was successfully applied in vertebral angiography by RADNER in 1947. The development of the SEIDINGER instrumentarium in 1953 further encouraged the use of this method. Its value in vertebral angiography is by now well established (CRONQVIST 1961) but it has also been increasingly applied in angiography of the carotid artery either by introduction of the catheter from the brachial, axillary or femoral arteries, or by direct catheterization of the common carotid artery (AMUNDSEN et coll. 1963). One point in favour of this technique is that it is probably without most of the drawbacks encountered with direct needle puncture. Furthermore, catheterization from the femoral artery causes only minor discomfort to the patient. It permits selective catheterization of the external and the internal carotid arteries after demonstration of the common carotid artery and enables the examination of more than one vessel in the same sitting.

Complications due to the technique with the catheter are however known to occur. Single reports on cerebral embolization in addition to local complications such as haematoma, local spasm, have been published. Seven such cases are reported in this paper to stress the existence of the risk. The angiographic changes and the clinical symptomatology compatible with the occurrence of acute embolization arising from an angiographic examination, together with preventive measures, will be discussed.

Technique. Vertebral and, in selected cases, carotid angiography are performed with catheterization via the femoral artery. The proportion at our department of direct to indirect approaches in the carotid examinations is about 50/50. A red Ödman-Ledin catheter is generally used, either a thin walled catheter with an outer diameter of 1.8 mm and an inner diameter of 1.2 mm, or a thick walled with an outer diameter of 2.2 mm and inner diameter of 1.2 mm. No side holes are introduced. The catheter is shaped in a more or less marked S form according to the age of the patient and the vessel to be examined. Thus the S has a sharper curve for the left than for the right carotid artery and for examining older patients. During the examination the catheter is intermittently flushed with saline during the period it takes to manipulate it in the correct position as well as when it is properly sited. If more than one vessel is to be examined the catheter tip is brought down into the lower part of the abdominal aorta in between catheterization of the individual vessels. The guide wire is then passed through the catheter to control free passage of blood through the lumen and the catheter is flushed



Fig 2
cereb
a ma
of on

of the middle cerebral artery not previously present was now seen. Peripheral to the defect the arteries were wider than normal and local slowing down of the circulation was noted. No neurologic signs developed in connection with the angiographic examination which was technically easy and rapidly performed.

Case 6 (Fig 4) Man aged 44 who had developed left-side paresis. About one month later angiography of the right internal carotid artery was performed with a catheter via the right femoral artery, and a small avascular expansive lesion in the parietal region was demonstrated. There were no signs of vascular occlusion. An additional angiographic examination was performed at the same session with the catheter in the common carotid artery and partial occlusion of a peripheral artery in the parieto-occipital region was demonstrated in the angiogram. The passage of contrast medium through the vessels was exceptionally slow in comparison with that in the other arteries. The vessel also appeared markedly dilated compared with its width at the first injection. No neurologic signs developed.

Case 7 (Fig 5) Woman aged 45 operated on 4 years previously for an angioblastic parasagittal meningeoma in the occipital region, complained of paresthesia in the left ear. In spite of no neurologic signs further angiographies were performed. The examinations were carried out with a catheter via the femoral artery and commenced with left carotid angiography. Injections were made first into the external and then into the internal carotid artery with filling of a normal left posterior cerebral artery. At subsequent left vertebral angiography a 2 mm long filling defect was present in the previously normal posterior cerebral artery. The patient developed no neurologic signs.



Fig 2 Case 4 Normal vertebral angiography (a) Carotid angiography (b) performed immediately after showed a collateral circulation to the peripheral branches of the posterior cerebral artery. This case represents an example of indirect signs of acute embolization.

sided carotid angiography via a catheter from the right femoral artery was performed under general anesthesia and two film series were taken in lateral projection. In the first series multiple occlusions were noted with a contrast blush and early filling of local veins in the region of the occlusion. The second series obtained five minutes later presented completely normal conditions. Neurologic examination after the patient had recovered from the anesthetic revealed no new clinical signs.

Case 4 (Fig 2) Woman aged 42 with acute headache was admitted and the diagnosis of subarachnoid haemorrhage was made. Bilateral carotid angiography and vertebral angiography were performed. Right carotid angiography was normal. This was followed by a left side vertebral catheterization via the femoral artery with entirely normal findings. These examinations were completed with left carotid angiography and retrograde filling of arteries corresponding to peripheral branches of the posterior cerebral artery was now present. This artery had been normally filled in the preceding vertebral examination. There were thus indirect signs that an occlusion had suddenly occurred in the artery. There were no neurologic signs.

Case 5 (Fig 3) Man aged 50 with papillary stasis had been examined at another hospital with angiography of one vertebral artery and of both carotid arteries. No gross changes were reported but the sigmoid sinus was not properly seen. Thrombosis of the latter was considered probable hence a repeat left carotid angiography was performed with the catheter introduced via the right femoral artery. A local filling defect



Fig 5 Case 7 Vertebral angiography (a) disclosed a filling defect in the posterior cerebral artery. This artery a few minutes later was seen to fill normally at carotid angiography (b)

between 3 and 6 per cent with about 80 per cent of lesions transient. Fatalities occurred in 0.7 per cent of cases. The number of cases of embolization was unknown.

Reports on complications with the catheter technique are predominantly based upon experiences from abdominal and thoracic angiography (McGraw 1963; KOTTKE *et al.* 1964; LANG 1966; SEIDENBERG & HURNITT 1966). These mainly deal with changes at the puncture site and within the vessels caused by the wire guide or by the catheter itself, i.e. a local haematoma and arterial spasm (WICKBOOM & BARTLEY 1957).

A large number of procedures, 11 402 in all, were collected and recorded by LANG (1963) who reported a mortality rate of 0.06 per cent and a serious complication rate of 0.7 per cent. Thromboembolic complications were noted in nine of the cases, corresponding to 0.07 per cent.

Data on complications in cerebral angiography performed with the catheter technique are scarce. Some information is available in earlier work on vertebral angiography by RADNER (1947) and by HALGE (1954) but to our knowledge little has been written regarding the technique applied today. FLIVIN (1960) reported his experiences with the catheter method in carotid angiography.



Fig 4 Case II Normal internal carotid angiography in (a) Subsequent common carotid angiography (b) showed occlusion of a peripheral branch in the posterior parietal region. No dilatation of occluded artery

Comments

All but one of the seven patients had more than one vessel examined at the same sitting. The duration of the procedures varied up to 80 minutes (Case 9 left internal and external carotid angiography and vertebral angiography). The contrast medium was Urografin 60 %. In four cases, no neurologic signs developed in relation to the examinations. Transient signs occurred in two cases, in one lasting only a few minutes and in the other about half an hour.

The embolus was in one case demonstrated by an arterial occlusion. It was directly seen in angiography as an intra-arterial filling defect in five cases, in one of which multiple defects indicated multiple emboli. In the latter case, local accumulation of contrast medium was seen during the capillary phase and early filling veins were observed in the region of the embolized vessel. Indirect signs of embolization, evident from the development of collateral circulation, were recorded in one case (Case 5). In addition to these signs there was almost always local slowing down of the passage of contrast medium in the partly occluded vessel which in some instances appeared markedly dilated.

Discussion

The incidence of complications in cerebral angiography performed with direct puncture is well documented. SCHEINBERG & ZUNKER (1963) from data available in the literature determined that the frequency of cerebral complications varied

marked circulatory disturbances evident in the angiograms. The signs may persist, but judging from the present series they appear to be mainly transitory in character. In some of the cases they actually passed off so fast that only the constant observation of the patient during angiography revealed their occurrence. Slow regression of symptoms was noted in only one case, although complete return to normal was delayed until a week after the incident.

The source of the embolus may be atherosclerotic plaques from which atheromatous material is dislodged by the catheter. On the other hand, the source may be the catheter itself. Thus, clots have been reported to form within the side holes close to the tip of the catheter (OUR 1953), and because of this the use of such catheters in selective angiography should be avoided (BOIJSEN & FRANKSTEIN 1961).

JACOBSSON (1967) recently proved that a catheter introduced into vessels is coated by a layer of platelets and that these may form thrombotic masses on the surface of the catheter, and probably also within the lumen of the catheter unless flushed away. The thrombotic material may easily get detached during the manipulation of the catheter and constitute the main source of emboli noticed during arteriography. There is evidence that the adhesiveness of platelets increases when the catheter is a long one and there are reasons to believe that the more irregular the wall of the catheter the greater is the tendency for clot formation.

The time during which the catheter remains within the vessel must also be of importance. Consequently, only catheters with the smoothest surface should be used, and the examination time must be short. From a practical standpoint this entails that when performing catheterization for angiography of more than one cerebral vessel the catheter should be changed between each examination. A constant infusion of saline instead of intermittent injections may be of value in preventing the formation of intraluminal clots. An additional precaution suggested and used by JACOBSSON in the infusion of macrodex prior to angiography

10-1

W. W. W. (GROENBERG et coll 1966)

The catheter method in comparison with direct needle puncture possesses many advantages in cerebral angiographic work. The risk of embolization remains, however. Since there are often no or only vague clinical indications that a vascular accident has occurred, there is a risk that an arterial embolization may be easily overlooked. The risk of not making the diagnosis, and thus also of getting a false impression of the safety of the catheter technique, is further enhanced by the fact that angiographic changes caused by an arterial embolus may be discreet and as such difficult to observe.

thought to be due to the toxicity of the contrast medium. In two additional cases spasm occurred around the tip of the catheter without development of neurologic signs.

A series consisting of 853 carotid and 118 vertebral angiographies performed with the catheter technique was reported by AMUNDSEN et coll (1963). They recorded severe complications attributed to angiography in only three cases. In an additional fifteen cases major accidents occurred during the post-angiographic period. However, according to the authors these could not be attributed to the angiographic procedure. No embolization occurred in their series. ZATZ & IANNOFF (1966) described three cases with embolization complicating cerebral angiography, in one of these a catheter with side holes was used. In all three cases neurologic symptoms developed in relation to the injection of the contrast medium.

An embolus may be directly seen at angiography as a filling defect within the lumen of an artery or as a complete occlusion of the vessel. In connection with catheterization it will probably occur in small arterial branches. The experimental observations of LUFSSFNHOP et coll (1962) suggested that these branches usually belong to the SYLVIAN group. The presence of an occlusion may also be evident as a local slowing down of the passage of contrast medium or by the presence of a collateral circulation. These signs may be present without simultaneous registration of the site of occlusion. The same applies to the local accumulation of contrast medium during the capillary phase and the early filling of a local vein, the known signs of an arterial lesion (CRONQVIST & LAROCHE 1967).

According to our experience, dilatation of the artery peripheral to the site of the embolus is a common and important angiographic finding. Whenever widening of a local vessel is seen, there will be reason for a careful study of the films in order to confirm or exclude partial occlusion in the central part of that vessel. As ZATZ et coll (1965, 1966) pointed out "the finding of multiple small occlusions in different vessels at the onset of a complication" is suggestive of arterial embolization. The diagnosis of an embolus is definite when the defect caused by the clot at angiography is seen to be migrating within the lumen of an artery. Further proof is present when a normal angiogram immediately precedes or follows the examination demonstrating the lesion. In the last-mentioned spontaneous lysis, i.e. rapid disappearance of an occlusion or an arterial filling defect, has taken place, a factor in favour of the diagnosis of an embolus. The diagnosis will be further strengthened by the appearance of new neurologic signs. These may be severe, with loss of important functions depending upon the size of the artery and the region affected. They may also, however, be very slight and revealed only by close observation of the patient during the procedure. There were even in our series two cases which presented no neurologic signs whatsoever despite the

marked circulatory disturbances evident in the angiograms. The signs may persist but judging from the present series they appear to be mainly transitory in character. In some of the cases they actually passed off so fast that only the constant observation of the patient during angiography revealed their occurrence. Slow regression of symptoms was noted in only one case, although complete return to normal was delayed until a week after the incident.

The source of the embolus may be arteriosclerotic plaques from which atheromatous material is dislodged by the catheter. On the other hand, the source may be the catheter itself. Thus clots have been reported to form within the side holes close to the tip of the catheter (OLIN 1963), and because of this the use of such catheters in selective angiography should be avoided (BOIJSEN & FEINSTEIN 1961).

JACOBSSON (1967) recently proved that a catheter introduced into vessels is coated by a layer of platelets and that these may form thrombotic masses on the surface of the catheter, and probably also within the lumen of the catheter unless flushed away. The thrombotic material may easily get detached during the manipulation of the catheter and constitute the main source of emboli noticed during arteriography. There is evidence that the adhesiveness of platelets increases when the catheter is a long one and there are reasons to believe that the more irregular the wall of the catheter the greater is the tendency for clot formation.

The time during which the catheter remains within the vessel must also be of importance. Consequently, only catheters with the smoothest surface should be used and the examination time must be short. From a practical standpoint this entails that when performing catheterization for angiography of more than one cerebral vessel the catheter should be changed between each examination. A constant infusion of saline instead of intermittent injections may be of value in preventing the formation of intraluminal clots. An additional precaution suggested and used by JACOBSSON in the infusion of macrodex prior to angiography (1967)

has been

ventilation

...

The catheter method in comparison with direct needle puncture possesses many advantages in cerebral angiographic work. The risk of embolization remains, however. Since there are often no or only vague clinical indications that a vascular accident has occurred, there is a risk that an arterial embolization may be easily overlooked. The risk of not making the diagnosis, and thus also of getting a false impression of the safety of the catheter technique, is further enhanced by the fact that angiographic changes caused by an arterial embolus may be discreet and as such difficult to observe.

Because of this, constant and thorough observation of the patient during and after an angiographic study is important. Furthermore we want to stress the diagnostic importance of the indirect signs of vascular occlusion, i.e. slowing of local circulation, collateral circulation or dilatation of a partially occluded vessel as observed in some of our cases.

SUMMARY

Seven cases of embolization during cerebral angiography are described. Continuous infusion of saline and, in cases in which more than one vessel is to be studied, a fresh catheter for each procedure may lessen the risk. The value in the routine use of macrodex is diminished by the large amount needed.

ZUSAMMENFASSUNG

Es wird über sieben Fälle von Gehirnembolie während cerebraler Angiographie berichtet. *Andauernde Infusion mit Salzlösungen und Katheterwechsel, falls mehrere Gefäße katheterisiert werden, mögen wohl das Risiko der Embolie vermindern.* Die routinemässige Anwendung von Makrodex ist praktisch erschwert, weil besonders grosse Mengen nötig sind.

RÉSUMÉ

Description de sept cas d'embolie au cours d'angiographie cérébrale. La perfusion continue de sérum salé physiologique, et dans les cas où il faut étudier plusieurs vaisseaux, l'utilisation d'un cathéter différent pour chaque angiographie, peuvent diminuer le risque. La nécessité d'utiliser de grandes quantités de macrodex limite son intérêt dans la pratique courante.

REFERENCES

- ADAMS D I, OLIN I B and KOSLEK J Cotton fiber embolization during angiography. *Radiology* 84 (1965), 678
- ALLEN J H, PARFRA C and PORTS D G The relation of arterial trauma to complications of cerebral angiography. *Amer J Roentgenol* 95 (1965), 845
- AMUNDSEN P, DIETRICHSON P, ENGE I and WILLISJON R Cerebral angiography by catheterization — complications and side effects. *Acta radiol Diagnosis* 1 (1963), 161
- BOJSEN E and FEINSTEIN G L Arteriographic catheterization technique. *Amer J Roentgenol* 85 (1961), 1037
- CRONBERG S, ROBERTSON B, NILSSON J M and NILLIN J-E Suppressive effect of dextran on platelet adhesiveness. *Thrombos Diathes haemorrh (Stuttg)* 16 (1966), 381
- CRONQVIST S Vertebral catheterization via the femoral artery. *Acta radiol* 55 (1961), 113
- and LAROCHE F Transitory 'hyperaemia' in focal cerebral vascular lesions studied by angiography and regional blood flow measurements. *Brit J. Radiol* 40 (1967), 270
- DECKER K *Klinische Neuroradiologie* G Thieme Verlag, Stuttgart 1960
- EIKEN M and GORMSEN J Complications of carotid angiography in acute cerebrovascular conditions. *Acta med scand* 172 (1962), 151

- ELFVIN P. Angiography of internal carotid with catheter technique. *Radiology* 75 (1960), 80
- FARIÑE P. L. New technique for arteriographic examination of abdominal aorta and its branches. *Amer J Roentgenol* 46 (1941), 641
- HÄLGE I. Catheter vertebral angiography. *Acta radiol* (1954) Suppl No 109
- ICHIKAWA T. Schatten der Nierenarterie. *Zeitschr Urol* 32 (1938), 563
- JACOBSSON B. Use of dextran in prophylaxis against thromboembolic complications in arterial catheterization. *Acta chir scand* (1967) Suppl No 387
- KOTTKE II A, FAIRBAIRN J F and DAVIS G D. Complications of aortography. *Circulation* 30 (1964), 843
- LANG E. K. Complications of percutaneous retrograde arteriography. *Radiology* 81 (1963), 257
- Complications in angiography of the brachiocephalic vessels. *Acta radiol Diagnosis* 5 (1966) 296
- LESTER J. Arteriovenous fistula after percutaneous vertebral angiography. *Acta radiol Diagnosis* 11 (1966) 337
- LLESSENHOFF A J, GIBBS M and VELASQUEZ A C. Cerebrovascular response to emboli. *Arch Neurol* 3 (1967), 264
- MCGRAW J Y. Arteriography of peripheral vessels. *Angiography* 14 (1963), 306
- MARGOLIS G, TINDALL G T, PHILLIPS R I et coll. Evaluation of roentgen contrast agents used in cerebral arteriography. *J Neurosurg* 15 (1958), 30
- OLIN T. Studies on angiographic technique. Håkan Olssons Boktryckeri, Lund 1963
- OLSON R W, BAKER H L and SVEN II J. Arteriovenous fistula: a complication of vertebral angiography. *J Neurosurg* 20 (1963), 73
- RADNER S. Intracranial angiography via vertebral artery. *Acta radiol* 28 (1947), 838
- RIVPAL A und SEILS H. Pathologisch anatomische Befunde an der Punktionsstelle bei der Hirnarteriographie und Betrachtungen zur Punktionstechnik. *Fortschr Röntgenstr* 87 (1957) 191
- SCHIEBERG P and ZILKER II. Complications in direct percutaneous carotid arteriography.
- SELDINGER S I. Catheter replacement of the needle in percutaneous arteriography. *Acta radiol* 39 (1953) 368
- TUNNIS W und SCHIEFER W. Zirkulationsstörungen des Gehirns im Serienangiogramm. Springer Verlag, Berlin 1959
- ZATZ L M and FANNONE A M. Cerebral emboli complicating cerebral angiography. *Acta radiol Diagnosis* 5 (1966), 621
- — — ECKERMAN P B and HECKER II P. Observations concerning intracerebral vascular occlusions. *Neurology* 15 (1965) 389
- WICKBOM I and BARTLEY O. Arterial 'spasm' in peripheral arteriography using the catheter method. *Acta radiol* 47 (1957) 433

ROENTGENOLOGIC ANGULATION MEASUREMENT IN SUPRACONDYLAR FRACTURES OF THE FEMUR

by

O LINDAHL and A MOVIN

An important problem in the treatment of fractures, especially of those of the long bones, is the determination of any incorrect angulation that may persist after reduction. The position of the fracture may usually be judged with the conventional roentgen technique, with projections in two planes at right angles to each other, parallel to the length of the bone. An evaluation of the third plane—a possible rotatory malposition—is more difficult to obtain with the ordinary technique, and examiners usually content themselves with an estimation of indirect roentgen signs in combination with the clinical assessment.

If the fracture is situated close to the joint, its position is sometimes difficult to determine with the ordinary examination in the two 'simple' longitudinal planes. Supracondylar fractures of the elbow and the femur may be cited as examples. Because of the absence of readily definable longitudinal surfaces at the articular ends of the bones, determination of the position of the peripheral fragment is more or less impossible. KEATS *et coll.* (1966), in an exhaustive survey, gave exact reference planes and methods for angle estimation for most of the large joints of the body, but just the regions mentioned above were omitted. The position of the femoral condyles in relation to the long axis of the femur (*genu vara*, *genu valga*) is readily defined in the frontal plane, but no method has been given for assessing a possible malposition in the sagittal plane.

The present authors, when carrying out roentgenologic and clinical studies of knee joint function (LINDAHL & MOVIN 1967), found that a structure in the



Fig. 1 Lateral views of knee joints with reference lines traced for angulation measurements a) Arrow indicates a depress on in the anterior surface of the lateral femoral condyle b) Knee joint with a supracondylar fracture of the femur angle 3° (in the sound knee 38°) c) Same as in (b) but with an angle of 36° (in the sound knee 39°)

femur close to the knee joint, not previously considered in these connections, may be used as a basis for a relatively exact evaluation of angular deformities in the sagittal plane. This structure is the plane formed by the upper demarcation surface of the intercondylar fossa towards the femur and which, in the lateral projection, is depicted as a straight line. BLUMENSAAT (1938) used this line only for evaluating the position of the patella, and mentioned no values for angles in relation to the long axis of the femur. HULTEN (1929) also observed this plane, and stated that in order to gain an 'Einblick' into the intercondylar groove the direction of the central ray should be approximately 50° from the normal, perpendicular a p projection.

BRATTSTROM (1964) considered that BLUMENSAAT's line was not of much value in the assessment of the patella alta as the angle between this line and the long axis of the femur varies considerably. Variations ranging from 27° to 60° occurred in 200 knee joints of men, he made no mention of the roentgenographic technique, nor of the age distribution in the material. As the knees which we had studied roentgenographically for other reasons (LINDAHL & MOVIN 1967) did not seem to show any appreciable variations, and as the difference between the right and the left sides, in particular, was small, it was considered of interest to investigate these conditions in a larger series.

Material and Methods A series of 200 normal knee joints (100 subjects with

ROENTGENOLOGIC ANGULATION MEASUREMENT IN SUPRACONDYLAR FRACTURES OF THE FEMUR

by

O. LINDAHL and A. MOVIN

An important problem in the treatment of fractures, especially of those of the long bones, is the determination of any incorrect angulation that may persist after reduction. The position of the fracture may usually be judged with the conventional roentgen technique, with projections in two planes at right angles to each other, parallel to the length of the bone. An evaluation of the third plane—a possible rotatory malposition—is more difficult to obtain with the ordinary technique, and examiners usually content themselves with an estimation of indirect roentgen signs in combination with the clinical assessment.

If the fracture is situated close to the joint, its position is sometimes difficult to determine with the ordinary examination in the two 'simple' longitudinal planes. Supracondylar fractures of the elbow and the femur may be cited as examples. Because of the absence of readily definable longitudinal surfaces at the articular ends of the bones, determination of the position of the peripheral fragment is more or less impossible. KEATS *et coll.* (1966), in an exhaustive survey, gave exact reference planes and methods for angle estimation for most of the large joints of the body, but just the regions mentioned above were omitted. The position of the femoral condyles in relation to the long axis of the femur (*genu vara*, *genu valgus*) is readily defined in the frontal plane, but no method has been given for assessing a possible malposition in the sagittal plane.

The present authors, when carrying out roentgenologic and clinical studies of knee joint function (LINDAHL & MOVIN 1967), found that a structure in the

Results

A comparison between the right and left sides in the same patient revealed that the mean difference in the angle between the two sides was $0.2^\circ \pm 0.2^\circ$, with a maximum of 4° . The angle between the two lines for the total of 200 knees was on an average $34.0^\circ \pm 0.5^\circ$, ranging from 26° to 44° .

A depression, or groove often occurs in the anterior outline, usually in the lateral femoral condyle (Fig. 1a). We have found that with full passive extension of the knee, this depression always matches the anterior part of the tibial condyle plane and that these two structures usually fit into each other. This hollow, when present serves as an indication of how far the knee can be extended, and it is probably a direct result of mechanical pressure when ends of the bones collide in the extended position.

Discussion

In addition to the difficulty of replacing the fragments and of keeping them in position it is often hard in the reduction of supracondylar fractures of the femur to judge whether any sagittal angulation between them has occurred. As pain in the knee, exudate or blood in the joint and changes in the position of the fragments during attempts to stretch the knee often make it impossible to obtain information about the position of the fragments by full extension of the joint, the assessment usually has to be made wholly from the roentgenologic lateral view with the knee in a more or less flexed position. In this situation, the possibility of being able to determine the angle between the intercondylar plane and the long axis of the femur would seem to be of great value (Fig. 1b).

The method not only helps to reveal any angulation that may have arisen but also permits an assessment with an accuracy of a few degrees after a comparison has been made with sound knee. If there is a depression as previously mentioned in the anterior outline of the femoral condyle its position may assist in the evaluation of the joint in full extension. Over extension of the knee joint is possible in a fair number of cases (LINDAHL & MOVIN 1968). In such cases a corresponding flexion in the fracture is permissible — if for some reason an exact position cannot be achieved — without any risk of an extension defect arising after union, which might cause the knee to give away under weightbearing if stabilization by the quadriceps muscle is lacking.

If this roentgenologic method is not used it often happens that

it may even be necessary. Malposition in the direction of extension is less common but it occurs occasionally and produces a greatly

Fig 2 Reference lines traced for angulation measurements knee joints with angle of 62° (a) (in the sound knee 37°) and with angle of 30° (b) (in the sound knee 33°)



a wide range as to age) were submitted to roentgen examination. The age and sex distribution in the material is presented below.

	< 20 years	20—50 years	> 50 years	Total
Men	14	16	17	47
Women	17	9	27	53
Total	31	25	44	100

The investigation comprised patients without knee complaints who had presented themselves for disease in other regions. The requirements set up for the lateral views were that the demarcations of the lateral and medial condyles of the femur, distally and posteriorly, should be parallel to a deviation between the parallelism of the two outlines not exceeding 2 mm. The focal film distance was 100 cm, and the film was placed close to the lateral side of the knee joint.

The plane for the floor of the intercondylar fossa (the intercondylar plane) was traced on the roentgen films, and the anterior cortical demarcation of the femoral shaft was used as the long axis of the femur. This outline is usually absolutely straight within a decimeter long area above the femoral condyles, whereas the posterior femoral outline is more or less curved and the midline is sometimes difficult to define, especially in the presence of fractures, which not infrequently involve the posterior surface of the femur. The angle between the anterior outline of the femur and the intercondylar plane was measured on the film (Fig 1a).

MOTILITY OF DIAPHRAGM IN CHILDREN WITH BRONCHIAL FOREIGN BODIES

by

GEORG THEANDER

A foreign body in a major bronchus may produce radiologic changes in the aeration of the lungs as well as in the position of the mediastinum and the diaphragm. As pointed out by JACKSON *et coll* (1920) and MANGES (1922), the lung may become hyperaerated or atelectatic peripheral to the foreign body, with consequent depression or elevation, respectively, of the ipsilateral hemidiaphragm, furthermore the mediastinum may deviate away from the side with hyperaeration or towards the side with atelectasis. These changes are, however, not always sufficient to indicate the site of an invisible foreign body because atelectasis in one lung, or in part of a lung, is often accompanied by hyperaeration of the other lung, or of other parts of the same lung, and vice versa.

Conclusive evidence of the site of a foreign body may often be obtained by demonstrating a change in position of the mediastinum during respiration (MANGES 1922, KEIJSER 1930, LEAK 1933, WESTERMARK 1938 and others). Like the other signs, however, this is not always sufficient to indicate the site of a foreign body.

is no

it de

in the case of a child with a foreign body during inspiration (or sniffing) and towards the opposite side during expiration (or coughing).

Submitted for publication 11 February 1969

'over-extended' knee joint. This also causes considerable discomfort, although to a lesser degree.

The possibility of using the intercondylar plane for angulation assessment in connection with fractures does not seem to have received much attention. Neither has it been recognized that the inter-individual variation between right and left knees is very small. We can find no explanation for the greater variations in BRATTSTROM's material except that possibly the roentgenograms were not obtained with the object in view to elucidate the problem discussed in this paper. Rotation in the long axis of the bone, and raising or lowering of the central ray in relation to the joint space, are unfortunately common occurrences at routine examinations, and they affect all angle values in the films.

SUMMARY

The angle between a plane through the roof of the intercondylar fossa and the long axis of the femur was measured in roentgen films taken with the central ray perpendicular to the sagittal plane. The mean value for this angle was $34.0^\circ \pm 0.5^\circ$ with a range of from 26° to 44° . When the right and left sides were compared in the individual patients the mean difference in the angle was found to be $0.2^\circ \pm 0.2^\circ$.

ZUSAMMENFASSUNG

An Röntgenaufnahmen des Knies mit dem Zentralstrahl senkrecht zur Sagittalebene wurde der Winkel zwischen der Längsachse des Femurs und einer Ebene durch das Dach der Fossa intercondylaris gemessen. Es ergab sich ein Mittelwert von $34^\circ \pm 0.5^\circ$ mit einer Streuung von 26° bis 44° . Ein Vergleich beider Seiten zeigte Unterschiede von $0.2^\circ \pm 0.2^\circ$.

RÉSUMÉ

Les auteurs ont mesuré l'angle que font un plan passant par le toit de l'enchâssement intercondylienne et l'axe longitudinal du fémur, sur des films pris avec un rayon central perpendiculaire au plan sagittal. La valeur moyenne de cet angle est de $34.0^\circ \pm 0.5^\circ$ avec un intervalle de 26° à 44° . Quand on compare les côtés droit et gauche d'un même sujet la différence moyenne de ces angles est de $0.2^\circ \pm 0.2^\circ$.

REFERENCES

- BLUMENSAAT C. Die Lagerabweichung und Verrenkungen der Kniescheibe. *Ergebn. Chir. Orthop.* 31 (1938), 149.
- BRATTSTROM H. Shape of the intercondylar groove normally and in recurrent dislocation of patella. *Acta orthop. scand.* 34 (1964) Suppl. No. 68.
- HULTÉN O. Über die indirekten Brüche des Tibiakopfes. *Acta chir. scand.* 66 (1929) Suppl. No. 15.
- KEATS T., TEESLINK R., DIAMOND A. and WILLIAMS J. Normal axial relationship of the major joints. *Radiology* 87 (1966), 904.
- LINDAHL O. and MOVIN A. The mechanics of extension of the knee joint. *Acta orthop. scand.* 38 (1967), 226.
- — Active extension capacity of the knee joint in the healthy subject. *Acta orthop. scand.* 39 (1968), 203.

Table 1

Twenty three children with a verified foreign body in a major bronchus

Case	Sex	Age	Foreign body	Site of foreign body	Interval	Conventional film pairs		Cine films	
						I	II	I	II
1	♂	4 y	Metal screw	RMB	2 w	—	—	—	—
2	♀	1 y	Metal tube	RMB	5 w	1	1	—	—
3	♀	9 m	Maize corn	RMB	1 d	2	2	—	—
4	♂	2 y	Piece of apple	RMB	1 d	1	1	—	—
5	♀	2 y	Piece of peanut	RMB	1 d	1	2	1	—
6	♀	11/2 y	Piece of wood	RMB	4 w	—	2	1	1
7	♀	2 y	Piece of nut	RMLB	<1 d	1	1	—	1
8	♂	1 y	Piece of carrot	RMLB	<1 d	2	1	—	—
9	♀	4 y	Leg of clock	RLLB	<1 d	—	—	—	—
10	♂	5 y	Spiral spring	RLLB	<1 d	1	1	—	—
11	♂	10 y	Piece of apple	RLLB	<1 d	1	2	—	—
12	♀	4 m	Metal wire	LMB	<1 d	—	—	—	—
13	♀	3 y	Pin	LMB	<1 d	—	—	—	—
14	♂	10 m	Tack	LMB	<1 d	—	—	—	—
15	♂	11/2 y	Tack	LMB	<1 d ²	1	1	—	—
16	♂	3 1/2 y	Piece of carrot	LMB	<1 d	2	1	—	—
17	♂	2 y	Piece of peanut	LMB	<1 d	—	3	1	—
18	♂	11/2 y	Piece of nut	LMB	1 w	1	1	1	—
19	♀	1 y	Head of thistle	LULB	<1 d	4	1	1	—
20	♀	2 y	Pin	LB and lung tissue	?	1	—	—	—
21	♀	11/2 y	Pin	LULB	<1 d	—	—	—	—
22	♂	2 y	Piece of carrot	LLL	<1 d	—	—	—	—
23	♀	11/2 y	Piece of peanut	LLL	5 d	1	2	—	—

Conventional film pairs and cine films before (I) and after (II) removal of f b RMB—right main bronchus RMLB—right middle lobe bronchus RLLB—right lower lobe bronchus LMB—left main bronchus LULB—left upper lobe bronchus LB—larynx bronchus, LLLB—left lower lobe bronchus

main bronchus in seven, the left upper lobe bronchus in one, and the left lower lobe bronchus in three cases. In one case a metal needle had perforated the bronchial wall and was partly lodged in a lingular branch of the left upper lobe bronchus but mainly in the lung tissue. The types and sites of the foreign bodies are listed in Table 1, which also gives the interval between aspiration and radiologic examination and the number of various kinds of respiratory roentgen studies performed before and after removal of the foreign body.

The effect of a foreign body on the motility of the diaphragm seems to have received far less attention. It is known, however, that the respiratory movements of the diaphragm may be restricted on the side where a bronchial foreign body is present. This phenomenon has been recorded in many cases where foreign bodies have been aspirated and was produced experimentally by HASSLINGER & HITZENBERGER (1926) in a fluoroscopic study of the mediastinum and the diaphragm in volunteers with an olive-shaped metal body in one or more of the major bronchi. MANGES (1922), who accounted for 56 cases of foreign bodies in the airways, described the fluoroscopic findings in such cases and stated that "the affected diaphragm may be lower at expiration than at inspiration." HASSLINGER & HITZENBERGER, however, in the above-mentioned experiments found that neither forced respiration nor the Muller manoeuvre provoked any paradoxical movement of the diaphragm. On the other hand, cases of foreign bodies in the bronchi with paradoxical movements of the ipsilateral hemidiaphragm have been reported also by ZAWADOWSKI and by LESZCZYŃSKI (1958).

A complex disturbance of diaphragm movements recently observed by the present author in a child with a bronchial foreign body prompted a search for abnormalities in the position and motility of the diaphragm in previous cases of this condition. The paper now presented is concerned with a report on the diaphragmatic abnormalities recorded and with their relationship, if any, to other effects of the foreign bodies.

Material and Methods The chest films obtained in 27 children with verified foreign bodies in the bronchi were reviewed for abnormalities in the aeration of the lungs and in the position of the mediastinum and the diaphragm. In one of the cases, however, the initial examination disclosed pneumomediastinum and bilateral pneumothorax, and in three others there was evidence of foreign bodies on both sides. These four cases appeared unsuitable for the purpose of the investigation and were therefore excluded.

Of the remaining 23 cases (eleven boys and twelve girls, aged from 9 months to 10 years) each had a single foreign body which was metal in ten and vegetable in thirteen cases (see Table 1). In the latter cases, the foreign body was not discernible and could only rarely be located by means of the air present in the bronchi; its site was however usually evident from other radiologic observations as well as from the findings at subsequent bronchoscopy. In Cases 6 and 7, in which the foreign body was spontaneously removed by coughing and in which bronchoscopy was not performed, the localization had to be based upon the radiologic findings alone.

The locations noted were the right main bronchus in six cases, the right middle lobe bronchus in two, the right lower lobe bronchus in three, the left

The time at which the foreign body had been aspirated was uncertain in one case and unknown in another. In most cases, radiologic examination had been performed within one day of aspiration but in some cases the interval was longer and, in two cases, as much as 4 and 5 weeks.

In all the cases studied, at least one conventional a-p film of the chest had been obtained. In four of the ten cases with a metal foreign body and in all except three (Cases 6, 17 and 22) of the others such films had been obtained in expiration as well as in inspiration. In fifteen cases, similar pairs of films had been obtained at least once after removal of the foreign body. All examinations also included a lateral view of the chest. Cine-radiography had been performed during forced respiration in six cases (in the above-mentioned Cases 6 and 17 and two others before, in one case after, and in one both before and after removal of the foreign body). A total of 53 conventional a-p film pairs or cine films were available from the twenty three cases reviewed (Table 1). These were studied for respiratory changes of the lungs, mediastinum and diaphragm. In some cases a description of the findings made at fluoroscopy or roentgen TV could be extracted from the record sheets.

Results

Abnormalities other than the foreign body itself were observed in seventeen of the twenty three cases studied. They included changes in the aeration of various parts of the lungs, displacement and respiratory movement of the mediastinum, and abnormalities in the position and respiratory movements of the diaphragm. The main findings in each of these seventeen cases are specified in Table 2. Further data are summarized under the respective subheadings below and exemplified in case reports that follow.

Aeration of the lungs appeared normal in nine of the ten cases with a metal foreign body (all except Case 15) and in one with a vegetable foreign body (Case 4). In the other thirteen cases abnormal aeration was evident at least in the lung — or in the part of a lung — that corresponded to the bronchus harbouring the foreign body (see Table 2). Thus lung, or part of the lung, had evidence of atelectasis in four cases, hyperaeration in eight, and a combination of both in one case (Case 3). It usually underwent little or no respiratory variation in aeration. In one patient (Case 19) however, who had been studied repeatedly before removal of the foreign body, it initially presented signs of relative atelectasis after inspiration but slight hyperaeration after expiration, whereas 3 days later it was definitely atelectatic in all phases of respiration.

Abnormal aeration was frequently also evident in locations other than that

Table 2

Main abnormalities in seventeen out of twenty-three children with bronchial foreign bodies

Case	Site of foreign body	Change in aeration	Inspiratory movement of	
			Mediastinum	Diaphragm
2	RMB	0	0	↑
3	RMB	Λ(H)*	←	↓
4	RMB	0	←	↓
5	RMB	H	←	↑
6	RMB	H	←	↓↑
7	RMB	Λ	←	↓
8	RMB	Λ	←	↓
10	RMB	0	0	↑
11	RMB	H	←	↓
15	IMB	H	→	↑
16	LMB	H	•	↓
17	IMB	H	•	↓↑
18	IMB	H	•	↓
19	ILMB	(Λ) Λ**	→ 0	↑ ↓
20	IB and lung tissue	0	0	↑
22	ILMB	H	Not examined	
23	LLMB	Λ	→	↓

Λ — atelectasis, H — hyperaeration of lung tissue supplied by bronchus with foreign body. Broken arrow indicates restricted excursion *Λ in two lobes and H in one lobe **Examinations at 3 day intervals, progression of Λ



Fig 1 Case 2 Metal tube in right main bronchus in inspiration (a) and expiration (b) Inverted movement of the right hemidiaphragm

hemidiaphragm during one and the same phase of respiration. These complex disturbances, which are described in more detail in the reports on Cases 6 and 17, were demonstrated in cine films but were not detectable in conventional pairs of roentgenograms and may thus have been present also in cases not studied by the former method.

All disturbances observed in the motility of the diaphragm were found to occur on the side with a foreign body, and no definite abnormality of the opposite hemidiaphragm was seen in any case. The anomalous movements appeared largely independent of the actual position of the foreign bodies in the bronchi and presented no obvious relationship to the aeration of the lungs, but the complex disturbances in motility seen in two of the cases examined with cine films occurred in both cases on a side with hyperaeration, and in each the foreign body was lodged in a main bronchus. Restricted or inverted movements, on the other hand, were present in cases with apparently normal aeration as well as in some of those with atelectasis or hyperaeration in the ipsilateral lung (see Table 2).

Repeat examinations of Case 19 before removal of the foreign body indicated that the movements of the diaphragm were normal on the first occasion but were inverted 3 days later. This change in motility coincided with progression of the atelectasis peripheral to the foreign body, which was lodged in the left upper lobe bronchus, and with disappearance of respiratory movements of the mediastinum.

All examinations performed after removal of the foreign bodies indicated that abnormalities previously observed in aeration and in the position and motility of the mediastinum and diaphragm had disappeared, except that, in some cases,

supplied by the bronchus with a foreign body. Atelectasis of an entire lung was regularly accompanied by hyperaeration on the other side, whereas hyperaeration of one lung was not always associated with any visible atelectasis on the other side. Atelectasis or hyperaeration of part of a lung was sometimes associated with obvious hyperaeration or atelectasis, respectively, in other parts of the same lung and, occasionally, in the other lung. During respiration the aeration was usually seen to vary in the lung tissue not supplied by the bronchus that had a foreign body.

The *mediastinum* appeared normal in position in nine of the ten cases in which neither atelectasis nor hyperaeration was observed. However, respiratory studies had been performed in only three of these ten cases, and in one of them (Case 4) inspiration was accompanied by a shift of the *mediastinum* towards the side with the foreign body.

Of the thirteen cases with demonstrable atelectasis or hyperaeration, or with a combination of both, respiratory studies had been performed in all except Case 22 and had consistently revealed shift of the *mediastinum* during respiration. In some cases the *mediastinum* was displaced laterally throughout the respiratory cycle and then towards a side with atelectasis, in others it resumed its normal position or was even shifted towards the opposite side in inspiration or expiration. The direction of the shift was independent of the distribution of atelectasis and hyperaeration but, as expected, during the inspiratory phase the shift was always directed towards the side with a foreign body (see Table 2). In one case (Case 19) examined repeatedly, a respiratory shift of the *mediastinum* was observed on the first occasion but not on a following one, despite the progression of the atelectasis caused by the foreign body.

The *diaphragm* on the same side as the foreign body was elevated or depressed in all cases with atelectasis or hyperaeration, respectively, of the entire ipsilateral lung and in some with only limited changes in aeration. The respiratory movements of the *diaphragm* could be evaluated in sixteen cases: they appeared normal in five and anomalous in eleven cases. The abnormalities included restricted excursions (9 cases), inverted movements (6 cases), and complex disturbances of motility (2 cases).

The criteria used in the classification of the movements of the *diaphragm* were as follows. Respiratory excursions were classed as restricted if they were unquestionably smaller than normal, obviously smaller than at re-examination after removal of the foreign body, or confined to only part of the *diaphragm*. The movement was regarded as inverted if the *diaphragm* was at a higher level in inspiration than in expiration. The term complex disturbance was used to denote the combined occurrence of upward and downward movements of a

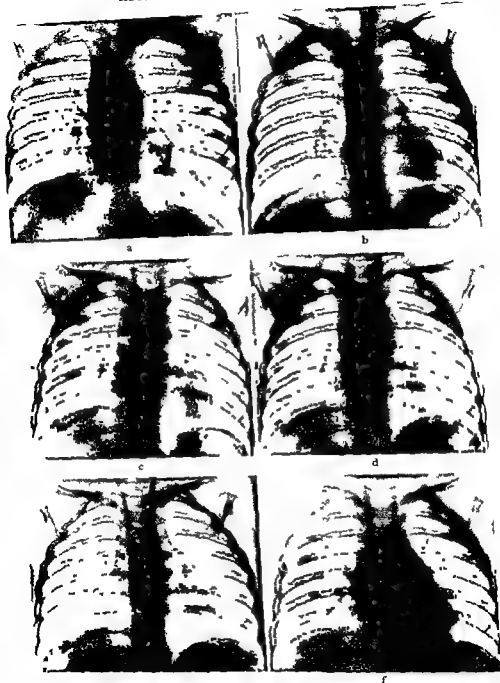


Fig 2 Case 5. Piece of peanut in right main bronchus (a) and (b) 1 day after its removal (c) and (d) 10 days after its removal (e) and (f) in inspiration (left) and expiration (right). Hyperaeration of the right lung and mediastinal shift are seen in (a) and (b) and inverted movement of right hemidiaphragm in (a) (b) (e) and (f).

minor residual atelectasis persisted for a few days. Case 5 was examined twice after bronchoscopic removal of a foreign body that had caused ipsilateral hyperaeration with displacement of the mediastinum and inverted excursion of the diaphragm. The findings were normal the day after operation but 11 days later inverted respiratory movements of the diaphragm had recurred.

Case reports

Case 2 A girl, aged 1 year, who had had repeated bouts of coughing for 5 weeks. Aspiration of a piece of a toy was considered likely. Radiologic examination revealed a thin metal tube with an inner diameter of 3 mm in the right main bronchus; one end of the tube was flanged and had an outer diameter of 7 mm. Ap chest films obtained in inspiration and expiration disclosed no abnormality in the aeration of the lungs and no obvious displacement of the mediastinum but revealed inverted respiratory excursion of the right hemidiaphragm (Fig 1).

The following day the foreign body was removed by bronchoscopy through an incision in the trachea. Radiologic re-examination one day later indicated slight mediastinal emphysema but otherwise nothing abnormal. The further postoperative course was uneventful.

Comments The films taken in inspiration and expiration had in this case also been obtained in different phases of the cardiac cycle and recorded marked differences in the width of the mediastinum and size of the heart. It is therefore uncertain whether a slight inspiratory shift of the mediastinum towards the right side occurred or not. The respiratory movements of the diaphragm were small on both sides, as compared with those of the ribs, but they were obviously inverted on the right side.

Case 5 A girl, aged 2 years, who was thought to have aspirated peanuts and had had attacks of coughing, was admitted for examination the following day. Physical examination revealed reduction of the breath sounds on the right side. Roentgenography of the chest demonstrated no foreign body but revealed hyperaeration of the left lung. This was most obvious in expiration. The mediastinum was slightly displaced to the right in inspiration and to the left in expiration. The respiratory excursions of the diaphragm were less on the right than on the left side and the level of the right hemidiaphragm in inspiration was higher than in expiration (Fig 2, a and b). Cineradiography during respiration confirmed these findings and indicated that the medial part of the right hemidiaphragm moved upwards during part of the inspiratory phase. A diagnosis of foreign body in the right main bronchus was made and at bronchoscopy the following day a piece of a peanut was removed from this bronchus.

Chest films obtained the day after bronchoscopy recorded normal aeration of both lungs, constant and normal position of the mediastinum and normal position of the diaphragm both in inspiration and expiration (Fig 2 c and d). Radiologic examination 11 days later however unexpectedly revealed abnormal motility of the diaphragm. Chest films in different phases of respiration disclosed that one hemidiaphragm moved upwards as the other moved downwards (Fig 2 e and f) and fluoroscopy during forced respiration demonstrated that the inverted movements occurred on the right side. Despite this recurrence of abnormal motility of the diaphragm the patient appeared healthy and no further radiologic examination was performed.

Comments The amplitude of the respiratory excursions of both hemidiaphragms as well as that of the ribs was greater before than after removal of the foreign body. The width of



Fig 4 Case II Sequence of cine films (20 frames/second) Complex disturbance of motility of right hemidiaphragm during forced inspiration

slope of the diaphragm decreased and the surface again became arcuate. During this final period of inspiration no movement of the mediastinum was visible.

A diagnosis of foreign body in the right main bronchus was made. The following day a pea sized piece of wood was coughed up. Chest films one day later disclosed no abnormality (Fig 3b) and examination by roentgen TV and cine films no longer demonstrated any abnormal movement of the mediastinum or diaphragm. Re-examination was performed again 4 weeks later, also with normal findings.

Case 17 A boy, aged 2 years, who had had an attack of coughing while eating peanuts, was admitted for radiologic examination the same day. No foreign body was seen but the

a p chest film on a level to the level of the diaphragm was high on both sides, though higher on the right than on the left side. Normal downward movement of the right hemidiaphragm on inspiration was recorded. The left hemidiaphragm initially also moved downwards, though less markedly than the right, but during a brief later period of inspiration its downward excursion was interrupted by rapid elevation of its medial part. During a final and still briefer period of inspiration this elevation was followed by a marked downward movement which brought the hemidiaphragm down to its lowermost level.

A diagnosis of foreign body in the left main bronchus was made, and at bronchoscopy the same day a piece of a peanut was removed from it. Radiologic re-examination, including chest films in inspiration and expiration, 1, 3 and 15 days later indicated nothing abnormal.

Case 19 A girl aged 1 year, admitted with probable aspiration of a foreign body, had been coughing for more than an hour with several bouts of marked dyspnoea. Physical ex-

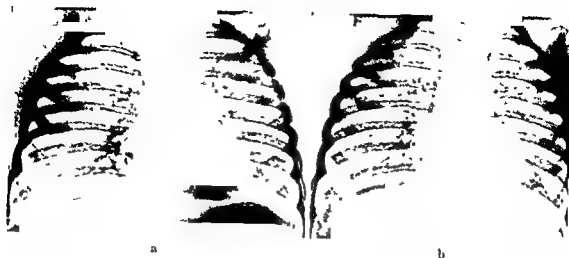


Fig 3 Case 6 Hyperaeration of piece of wood, before (a) and 1 day after (b) Hyperaeration of right lung with expansion of right hemithorax, displacement of mediastinum to the left and depression and flattening of the right hemidiaphragm in (a)

the chest and the slope of the ribs were equal in the films taken in inspiration and expiration at the final examination, in spite of a marked respiratory change in position of the diaphragm. The available conventional films alone were thus sufficient to reveal the inverted movements of the diaphragm but not to demonstrate whether they occurred on the right or left side. No explanation can be offered for the recurrence of abnormal motility of the diaphragm in this exceptional case.

Case 6 A girl, aged 18 months, who had had recurrent bouts of coughing for 4 weeks the initial attack having lasted for an hour. Physical examination of the chest revealed reduced breath sounds, prolonged expiration and sibilant rales over the base of the right lung. Chest films in inspiration disclosed no foreign body but demonstrated hyperaeration of the right lung, with marked expansion of the right side of the chest, slight displacement of the mediastinum to the left, and flattening and depression of the right hemidiaphragm (Fig 3a). No conventional film in full expiration was obtained but the patient was examined by roentgen TV and cine film during forced respiration (crying). Inspiratory shifting of the mediastinum towards the right side and a complex disturbance in the motility of the right hemidiaphragm were recorded. The motility of the left side of the diaphragm appeared normal.

The abnormal motility of the right hemidiaphragm is illustrated in Fig 4, which presents an inspiratory sequence of cine film frames taken at a rate of 20 frames/second. At the beginning of inspiration the medial part of the hemidiaphragm moved rapidly upwards for a brief period, after which the lateral part began to move downwards. The former movement preceded the rightward shift of the mediastinum, which commenced simultaneously with the downward movement of the lateral part of the diaphragm. As a result of these combined excursions the laterad slope of the entire hemidiaphragm increased and its previously arcuate appearance became slightly biarcuate. The medial part of the hemidiaphragm then remained steady while the lateral part continued its downward movement and the mediastinum moved slightly further to the right. However, at the end of inspiration the entire hemidiaphragm moved upwards, the lateral part more than the medial part so that the

amination revealed nothing abnormal, and no foreign body was visible in the chest films but the radiologic examination which included a cine film study of the chest during forced respiration suggested abnormal aeration of the left upper lobe. There was no change in aeration in this lobe during respiration which therefore appeared relatively atelectatic in full inspiration and slightly hyperaerated in expiration. During inspiration the mediastinum particularly the upper part moved considerably towards the left side. The left hemidiaphragm performed somewhat smaller respiratory excursions than the right but was situated at a lower level both in inspiration and expiration (Fig 5, a and b). A diagnosis of foreign body in the left upper lobe bronchus was made.

The symptoms rapidly subsided but on radiologic re-examination, which was performed twice the same day, the abnormal signs persisted. Bronchoscopy was carried out the following day but revealed nothing abnormal. Two days later radiologic examination, including fluoroscopy during forced respiration, was again performed. The left upper lobe was then definitely atelectatic throughout the respiratory cycle. The mediastinum was displaced to the left but no longer moved during respiration. The respiratory excursions of the diaphragm were not so great as previously but had clearly become inverted on the left side. As before, the left hemidiaphragm was at a lower level than the right in full expiration but both were at the same level in inspiration (Fig 5, c and d).

The following day bronchoscopy was repeated and this time a head of a thistle was removed from the left upper lobe bronchus. Radiologic re-examination of the chest a few hours later disclosed nothing abnormal. Both hemidiaphragms were at almost the same level and their respiratory excursions were equal (Fig 5 e and f).

Discussion

The respiratory movements of the diaphragm have been radiologically investigated by many authors, and several kinds of anomalous motility are on record, including restricted and inverted movements and various types of complex disturbances. DAVIS (1933), for example, in his roentgenkymographic studies of the diaphragm, observed paradoxical and pseudoparadoxical movements as well as 3 phase and 4 phase excursions, and even other varieties of respiratory movements. Since the present investigation was mainly based on a review of roentgenograms, distinction could not be made between all of these types of abnormalities. The inverted movements discovered merely by comparison of chest films obtained in inspiration and expiration may, for example, have been simple paradoxical or pseudoparadoxical excursions, or they may have been part of some more complicated disturbance in motility.

The various kinds of abnormal motility described by DAVIS were observed in several diseases including bronchostenosis caused by bronchial carcinoma in which a brief paradoxical phase of respiratory movement of the diaphragm appeared not only on the same side as the tumour but sometimes on the opposite side as well. Bronchostenosis caused by a foreign body does not seem to have been among the conditions investigated by DAVIS.

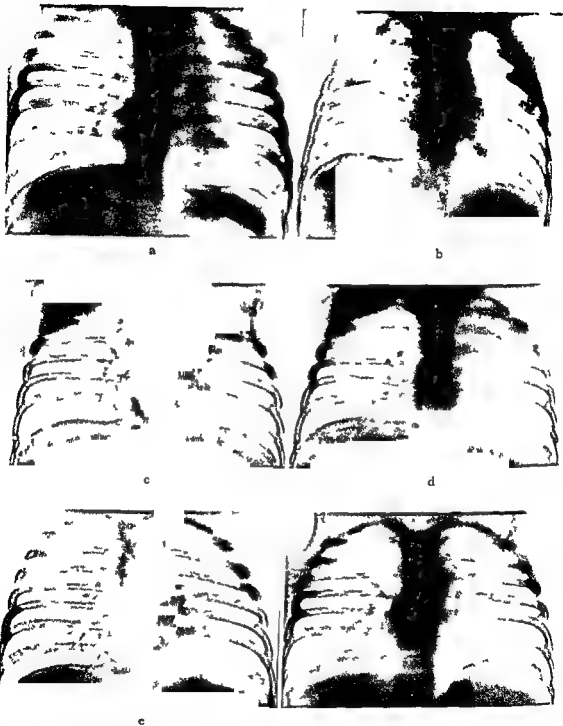


Fig 5 Case 19 Head of thistle in left upper lobe bronchus 4 days before (a) and (b) 1 day before (c) and (d) and a few hours after removal (e) and (f) in inspiration (left) and expiration (right) Mediastinal shift in (a) and (b) atelectasis of left upper lobe in (c) and (d) left hemidiaphragm lower than right in (a), (b) and (d) its excursion is less than that of the right in (a) and (b) and inverted in (c) and (d)

aeration was seen in only one (Case 15) of the ten cases in which the foreign body was metallic, and that respiratory studies, performed in four (Cases 2, 10, 15 and 20) of these ten cases, revealed inverted movements of the diaphragm regularly but in only one a respiratory shift of the mediastinum. It should be observed that in Case 20, in which inverted movement of the diaphragm but neither abnormal aeration nor any shift of the mediastinum were demonstrated, the foreign body was a metal needle lodged mainly in the lung tissue and only to a minor extent in a bronchus.

The independence observed between the effects of bronchial foreign bodies on the diaphragm and the effects on the aeration of the lungs and the mediastinum suggests that the abnormal motility of the diaphragm associated with foreign bodies in the bronchi may not be directly related to the bronchostenosis itself. Inverted movements of the diaphragm are known to occur also in various pathologic conditions other than bronchostenosis, such as after injury to the phrenic nerve. The passive respiratory movements of a completely paralytic hemidiaphragm are inverted and tend to be accompanied by shifting of the mediastinum. This shift differs from that in bronchostenosis in that it is directed towards the normal side during inspiration, but it is usually only slight and may easily be prevented or modified by co-existing disease (STEWART & GHISELIN 1939). Concomitant bronchostenosis and paralysis of the phrenic nerve on the same side would thus have antagonising effects on the mediastinum, the net result of which might produce no respiratory shift of the mediastinum at all or a shift that would be less marked than in either of these conditions separately but probably similar in direction to that produced by bronchostenosis alone.

It is an interesting possibility that a foreign body in a major bronchus may be accompanied by reflex inhibition of the innervation of the ipsilateral hemidiaphragm. This would modify the effect of the associated bronchostenosis on the mediastinum, it would thereby serve as a protective mechanism reducing the risk of severe circulatory disturbance inherent in any marked respiratory shifting of the mediastinum. It would also help to explain the occurrence of inverted movement of the diaphragm in cases of bronchial foreign bodies without any view it

is not

piratory studies before removal of the foreign body recorded no shift of the mediastinum belonged to those with inverted movements of the diaphragm. It should also be recalled that in Case 19 progression of atelectasis peripheral to the foreign body was accompanied, not by any increase, but by the disappearance of respiratory shifting of the mediastinum, and that this was associated with a change from normal to inverted excursions of the diaphragm. These observations would be plausibly explained by the protective mechanism suggested above and seem to

Various deviations from the usual pattern of motility of the diaphragm have also been recorded in apparently healthy subjects. The amplitude of the excursions during forced respiration is far from constant and may normally differ from one side to the other. BELFNOIT (1958) described a presumably healthy male in whom the movements of the diaphragm on voluntary coughing were occasionally inverted. The inversion sometimes affected the right and sometimes the left hemidiaphragm. According to ALEXANDER (1966), unilateral paradoxical movements of the diaphragm may be provoked by sniffing in 6 % of normal subjects, and then more often on the right than on the left side.

Such occasional normal deviations of motility might have been erroneously classified as abnormal in the present investigation, but this seems unlikely since in all cases re-examined after removal of the foreign body any previously demonstrated abnormality in motility proved to have disappeared. The invariable localization of the anomalous movements to the ipsilateral hemidiaphragm provides further evidence that these were truly abnormal and due to the presence of a foreign body in the airways.

The various types of abnormal motility of the diaphragm recorded in bronchostenosis have usually been attributed to a disturbed relationship between the changes in intrapleural and intraabdominal pressures during respiration. This relationship would seem likely to become disturbed particularly in bronchostenosis severe enough to produce atelectasis or hyperaeration of the entire ipsilateral lung. MANGES (1922), who seems to have been the first to have reported inverted movements of the diaphragm in cases of bronchial foreign bodies, also held the opinion that such movements occurred 'in severe cases'. In the present investigation, however, the motility of the diaphragm was largely independent of the aeration of the lungs. While invariably ipsilateral to the foreign body, inverted movements of the diaphragm were in two cases seen on a side with hyperaeration and, in one case on a side with atelectasis, however, they also occurred in three cases without any visible abnormality of aeration. On the other hand, they were not seen in all of the cases with marked atelectasis or hyperaeration.

HASSLINGER & HITZENBERGER (1926), in their aforementioned experiments with volunteers, occluded various bronchi with olive-shaped metal bodies that were either solid or perforated by longitudinal canals of different sizes. They observed no effect of the occlusion on the lungs, mediastinum or diaphragm unless the foreign body had reduced the lumen of a major bronchus by two-thirds or more, and the earliest effect discovered was a respiratory shift of the mediastinum. It is difficult to assess the degree of obstruction caused by the foreign bodies in the present cases because it may have been aggravated by stagnation of secretions and swelling of the mucosa, but it is noteworthy that abnormal

ZUSAMMENFASSUNG

Es wurde bei einer Analyse von Röntgenaufnahmen und Cinefilmen in 23 Fällen von Bronchialfremdkörpern bei Kindern beobachtet, dass verschiedene Bewegungsabnormalitäten der gleichseitigen Zwerchfellkuppe in 11 von den 16 Fällen auftraten, in denen die Atmungsbewegungen genau untersucht wurden. Die diagnostische Bedeutung solcher Bewegungsabnormalitäten konnte durch weitere Beobachtungen in diesen elf Fällen erleuchtet werden.

RÉSUMÉ

a été faite. Les constatations faites dans ces onze cas montrent l'intérêt diagnostique de ces mouvements respiratoires anormaux.

REFERENCES

- ALEXANDER C. Diaphragm movements and the diagnosis of diaphragmatic paralysis. *Clin Radiol* 17 (1966), 79.
- BELBENOIT M. Etude d'un mouvement diaphragmatique anormal au cours de la toux. *J franç Méd Chir thor* 12 (1958), 147.
- DAHM M. Rippen und Zwerchfellbewegung im Röntgenbild I: Bewegungsformen und Bewegungszusammenspiel. *Fortschr Röntgenstr* 47 (1933), 276.
- Rippen und Zwerchfellbewegung im Röntgenbild II: Paradoxe und pseudoparadoxe Zwerchfellbewegungen unter Berücksichtigung der mediastinalen Bewegungen. *Fortschr Röntgenstr* 47 (1933), 426.
- HASLINGER F. und HITZENBERGER K. Das Mediastinalwandern bei künstlicher Bronchusstenose. *Wien klin Wschr* 39 (1926), 1035.
- JACKSON C., SPENCER W. H. and MANGES W. F. The diagnosis and localization of non-opaque foreign bodies in the bronchi. *Amer J Roentgenol* 7 (1920), 277.
- KEIJZER S. Ventilstenose des Bronchus nach Aspiration von Fremdkörpern. *Röntgenpraxis* 2 (1930), 170.
- LENK R. Das Mediastinalschnellen, ein funktionelles Symptom bei Bronchostenosen geringen Grades. *Fortschr Röntgenstr* 47 (1933), 90.
- LESZCZYŃSKI M. Objawy radiologiczne rozdzicia wentylowego płuc (Summary in English). *Pol Przegl radiol* 22 (1958), 287.
- MANGES W. F. The roentgen ray diagnosis of non-opaque foreign bodies in the air passages. *Amer J Roentgenol* 9 (1922), 288.
- STEWART W. H. and GHISELIN F. H. The paradoxical movement of the diaphragm and mediastinal shift. Cinefluorographic studies. *Amer J Roentgenol* 41 (1939), 6.
- WESTERMARK N. On bronchostenosis: a roentgenologic study. *Acta radiol* 19 (1938), 285.
- ZAWADOWSKI W. Cited by LESZCZYŃSKI.

lend further support to the assumption that foreign bodies in the bronchi may exert part of their effect on respiratory dynamics by causing reflex inhibition of the innervation of the diaphragm.

The abnormal movements of the diaphragm recorded in cases of bronchial foreign bodies may be diagnostically important, particularly in two respects. As pointed out by DAHM (1933), inverted excursions of one hemidiaphragm may cause uncertainty as to whether a chest film obtained has been taken in inspiration or expiration and may therefore make it difficult to ascertain which side moves anomalously. In his opinion the slope of the ribs and the width of the chest in such cases are reliable indicators permitting radiologic distinction between the different phases of respiration. This view is supported by some observations made in the present series, as exemplified in Case 2 (Fig. 1). In Case 5, however, the slope of the ribs and the width of the chest were on one occasion equal in the films taken in both inspiration and expiration (Fig. 2, c and f). These films, though revealing inverted movement of the diaphragm, were thus insufficient to demonstrate whether the right or the left hemidiaphragm moved abnormally, and continuous observation of the respiratory movements proved necessary to make sure that the inverted excursions occurred on the right side but not on the left.

Abnormal movements of the diaphragm may on the other hand help to reveal the existence or the site of a foreign body in the airways. The present series included three cases (Cases 2, 10 and 20) in which this sign was demonstrated in the absence of any visible abnormality in the aeration of the lungs and without any shift of the mediastinum. The foreign bodies themselves were readily seen in these cases but if they had not been metallic the abnormal excursions of the diaphragm would, at least at the time of the examination, have been the only radiologic clue to the correct diagnosis.

Acknowledgement

Financial support by a grant from the Swedish National Association against Heart and Chest Diseases is gratefully acknowledged.

SUMMARY

A review of conventional and cine films of the chest in 23 cases of foreign bodies in the bronchi in children revealed various types of abnormal movements of the ipsilateral hemidiaphragm in 11 of 16 cases in which respiratory studies had been performed. Observations made in these eleven cases illustrated the diagnostic significance of such abnormal respiratory movements.



Fig 1 Case 1 Continuous gas filling in the intestinal tract there is a lobulated soft tissue mass in the right iliac fossa encephalochroaching upon the gas-filled colon but leaving a channel free for the gas to communicate with the caecal pole

ditions (KJELLEN 1955, KJELLEN et coll 1957, BELL & STEYN 1962) Thickening of the Peyer's patches has been observed in a proportion of cases of mesenteric adenitis coming to operation (AIRD 1945) The thickened Peyer's patches can lead to intussusception, which in due course will cause intestinal blood loss. On the other hand, sloughing of diseased Peyer's patches can lead to intestinal blood loss without intussusception (HAJDU 1955)

In the author's experience the diagnosis of enlarged mesenteric lymph nodes, to the exclusion of intussusception, can often be made by conventional roentgen examination of the abdomen. In a number of cases it could also be made as a reasonable alternative to the diagnosis of acute appendicitis, though not to the exclusion of the latter, since radiographically silent, pre perforative appendicitis and mesenteric adenitis may co-exist

For the past 16 years nearly all infants and children who presented with abdominal pain at our Paediatric Unit had, on admission, three antero-posterior films taken of the abdomen (1) supine, (2) erect and (3) left lateral recumbent. The total skin dose in the central axis of the beam varied between 0.15 and 0.27 R according to the age of the patients. During this time, 47 cases of intussusception and 72 cases of mesenteric adenitis were studied by the author. In the latter group a definite diagnosis of mesenteric adenitis could be made in 30 cases

MESENTERIC ADENITIS IN CHILDHOOD SIMULATING INTUSSUSCEPTION

by

NICHOLAS HAJDU

Acute non-specific mesenteric adenitis is a common disease in children. It is a frequent source of error in the diagnosis of the acute abdomen. AIRD, writing from the Surgical Unit of the Royal Edinburgh Hospital for Sick Children in 1945, reported that in a single year he found, on laparotomy, 37 cases suffering from non-specific mesenteric adenitis, compared with 83 suffering from acute appendicitis. The difficulty of distinguishing between mesenteric adenitis and acute appendicitis has been emphasized by many authors. Since objective proof of mesenteric adenitis short of laparotomy could not be obtained, surgeons tended to operate rather than to rely upon unsupported clinical evidence (JONES 1969).

The fact that acute mesenteric adenitis can closely simulate intussusception has received less attention. Yet prillor, colicky abdominal pain, a palpable mass in the right iliac fossa and admixture of blood to the stools are common to both. Furthermore, both intussusception and mesenteric adenitis tend to occur in small epidemics and the one is often etiologically related to the other (ROSS & POTTER 1961, GARDNER *et al.* 1962). The causative role of adenovirus 1, 2, 3, 5 and 6, and very occasionally E. C. H. O. 7 and 9 appears well verified in both con-

Part of this paper was read at the Reunion Internationale de Radiologie Pédiatrique in Paris May 1963. Submitted for publication 15 April 1969.

intestinal gas in the conventional position of the caecum. This is the visual equivalent of Dance's sign, i.e. the feeling of emptiness in the right iliac fossa on rectal examination.

3. The mass of the intussusception, which may be seen as an ovoid soft tissue mass. It may bulge into the colonic gas so as to produce a cup-shaped termination of the latter. It causes a gap between the gas of the small intestine and the gas in the large bowel, i.e. a discontinuity of gas filling. In the left lateral recumbent position the colonic gas fails to rise into the caecum and ascending colon.

When the intussusceptum is loose, signs of obstruction are absent. One has to rely chiefly upon the signs referable to the mass of the intussusception, listed under (3).

When shock is severe, gas is scant or completely absent. The radiologist is faced with the ominous picture of a 'grey abdomen'.

Mesenteric adenitis. The diagnosis of mesenteric adenitis is based upon positive findings, i.e. the visibility of enlarged lymph nodes, and negative ones, i.e. the absence of signs of intussusception.

The positive signs are as follows. In the supine and left lateral recumbent positions the mass of enlarged lymph nodes can appear as a lobulated soft tissue mass, particularly against a background of common meteorism (Fig. 1). Even smaller lymph nodes can produce pressure defects upon the medial wall of the caecum and ascending colon, particularly in left lateral recumbency (Fig. 2). These defects are extrinsic, often multiple, and involve the proximal third of the colon, whereas the filling defect caused by the head of the intussusceptum is intrinsic, single, and usually found in the middle third of the colon. An important feature was noted in left lateral recumbency: the enlarged lymph nodes could be seen through the gas content of the caecum and ascending colon in the shape of rounded masses, on the same principle as the kidneys can be seen through the gas-inflated stomach (Fig. 3). Usually both effects are present, i.e. the lymph nodes partly indent the gas of the colon and are partly overlapped by the same (Fig. 4). This double characteristic helps to distinguish them from scybala which produce intraluminal filling defects.

The negative signs are as follows. When the patient is placed into the left lateral recumbent position, the colonic gas rises into the caecum, i.e. there is no intussusceptum to interfere with the postural shift of colonic gas. In infants and small children where meteorism is the rule, it is usually obvious that there is no discontinuity of gas filling between the small and large intestine. No 1



Fig 2 Case 2 a) Supine film showing a fair amount of gas in the transverse colon b) In left lateral recumbent position the gas moved into the cecum and ascending colon Multiple extrinsic pressure defects are seen on the medial contour of the bowel caused by rounded masses of soft tissue

through direct demonstration of the enlarged lymph nodes. In the remaining 42 cases, a tentative diagnosis was made on the basis that the findings in conventional roentgenograms of the abdomen were contrary to the accepted signs of intussusception. Hence it seems appropriate in this context to give a brief review of these signs.

Intussusception The signs depend upon the degree of patency of the central canal and upon the severity of the associated shock. Most of these have been described in the literature (SCHATZKI 1939, HELLMER 1948, FRIMANN-DAHL 1951, MIDDLEMISS 1955, and others). The author's contribution is confined to observations in the left lateral recumbent position.

The intussusception can be very tight, moderately tight or loose. When very tight, it produces signs of complete, low, small-intestinal obstruction. When moderately tight, the roentgenologic signs fall into three groups:

- 1 Those representing partial obstruction, i.e. one or two fluid levels usually situated in the right iliac fossa.

- 2 Shortening of the colon. The most consistent sign is the presence of small



Fig 4 Case 4 Film obtained in left lateral recumbency The colonic gas shifted into the proximal colon the gas column in the caecum and ascending colon partly overlaps and is partly indented by rounded masses of soft tissue



Fig 5 Case 5 Film obtained in left lateral recumbency The colonic gas shifted into the proximal colon there are several enlarged lymph nodes which partly indent the colonic gas and are partly seen through it

Case 2 Boy aged 6 months with history and clinical signs on admission consistent with intussusception. The radiologic examination led to the diagnosis of mesenteric adenitis (Fig 2) and no treatment was given. The child was discharged home free of symptoms 3 days later.

Case 3 Boy aged 4 years was admitted with a 3 day history of abdominal pain first centred round the umbilicus but later located in the right iliac fossa. The pain was coming and going and colicky in character. The boy did not vomit, the bowels were rather loose. He looked pale, there were a few submandibular lymph nodes and on deep palpation a tender mass could be felt deep in the right iliac fossa.

Survey films of the abdomen are shown in Fig 3. A large lymph node was seen in left lateral recumbency. The child was discharged home the following day. Occult blood which was present on admission persisted for 14 days and full recovery took one month.

Case 4 Boy aged 4 years who 1 day before admission began to have abdominal pain which became worse during the last 24 hours. The pain lasted a few seconds, he screamed out with pain and doubled up. Clinical examination revealed a soft abdomen and a palpable descending colon but no masses were felt. The boy was kept under observation for 24 hours, he was still having central abdominal colicky pain, vomited once and had faeces in rectum. Intussusception was thought probable.



Fig 3 Case 3 a) Supine film showing no characteristic feature b) In left lateral recumbency the gas shifted from the transverse into the ascending colon a large mesenteric lymph node is now clearly seen through the gas

trinsic filling defects the diagnosis is mesenteric adenitis, when the gas does not rise to the caecum or when there is a single and intrinsic filling defect the diagnosis is intussusception

The following case reports are presented to exemplify our findings

Illustrative cases

Case 1 Girl aged 1 months. Screaming attacks followed by slightly blood stained constipated stools started 2 days before admission. She once vomited dark brown material. The screaming continued all the night before admission. On examination there was a doubtful mass in the right iliac fossa. (Several members of the family had had a sore throat during the previous month.)

Roentgen examination (Fig 1) revealed continuous gas filling in the intestinal tract. A lobulated soft tissue mass was seen in the right iliac fossa. It overlapped the gas filled colon but left a lateral channel free for the gas to communicate with the cecal pole.

Despite the definite radiologic evidence of mesenteric adenitis the clinicians decided to have a laparotomy performed. This revealed large mesenteric lymph nodes of the non specific variety. Blood was visible in the lumen of the small intestine but no pressure mark of past intussusception was observed. Some of the Peyer's patches were thickened and it was assumed that one must have sloughed away and caused the bleeding.



Fig 4 Case 4 Film obtained in left lateral recumbency The colonic gas shifted into the proximal colon, the gas column in the caecum and ascending colon partly overlaps and is partly indented by rounded masses of soft tissue



Fig 5 Case 5 Film obtained in left lateral recumbency The colonic gas shifted into the proximal colon, there are several enlarged lymph nodes, which partly indent the colonic gas and are partly seen through it

Case 2 Boy, aged 11 months, with history and clinical signs of intussusception. The radiologic examination (Fig 2) and no treatment was given 10 days later.

Case 3 Boy, aged 4 years, was admitted with a 3 day history of abdominal pain, first centred round the umbilicus but later located in the right iliac fossa. The pain was coming and going and colicky in character. The boy did not vomit, the bowels were rather loose. He looked pale, there were a few submandibular lymph nodes and on deep palpation a tender mass could be felt deep in the right iliac fossa.

Survey films of the abdomen are shown in Fig 3. A large lymph node was seen in left lateral recumbency. The child was discharged home the following day. Occult blood which was present on admission persisted for 14 days and full recovery took one month.

Case 4 Boy, aged 4 years, who 4 days before admission had

the boy was kept under observation for 24 hours, he was still having central abdominal colicky pain, vomited once and had faeces in rectum. Intussusception was thought probable.



Fig. 1. Case 3. a) Spot film showing no characteristic feature. b) In left lateral recumbency the gas shifted from the transverse into the ascending colon, a large mesenteric lymph node was clearly seen through the gas.

transverse filling defects the diagnosis is mesenteric adenitis, when the gas does not rise to the caecum or when there is a single and intrinsic filling defect the diagnosis is intussusception.

The following case reports are presented to exemplify our findings.

Illustrative cases

Case 1. Girl aged 1 month. Screaming attacks followed by slightly blood stained constipated stools started 2 days before admission. She once vomited dark brown material. The examination continued all the night before admission. On examination there was a doubtful mass in the right iliac fossa. Several members of the family had had a sore throat during the previous month.

Roentgen examination (Fig. 1) revealed continuous gas filling in the intestinal tract. A lobulated soft tissue mass was seen in the right iliac fossa. It encroached upon the gas-filled colon but left a lateral channel free for the gas to communicate with the caecal pole.

Despite the doubtful radiological evidence of mesenteric adenitis the clinicians decided to have a laparotomy performed. This revealed large mesenteric lymph nodes of the non-specific variety. Blood was visible in the lumen of the small intestine but no pressure was of past intussusception was observed. Some of the Peyer's patches were thickened and it was assumed that one must have sloughed away and caused the bleeding.



Fig 4 Case 4 Film obtained in left lateral recumbency. The colonic gas shifted into the proximal colon; the gas column in the caecum and ascending colon partly overlaps and is partly indented by rounded masses of soft tissue.



Fig 5 Case 5 Film obtained in left lateral recumbency. The colonic gas shifted into the proximal colon; there are several enlarged lymph nodes which partly indent the colonic gas and are partly seen through it.

Case 2 Boy aged 6 months with history and clinical signs on admission consistent with intussusception. The radiologic examination led to the diagnosis of mesenteric adenitis (Fig 2) and no treatment was given. The child was discharged home free of symptoms 3 days later.

Case 3 Boy aged 4 years was admitted with a 3 day history of abdominal pain first centred round the umbilicus but later located in the right iliac fossa. The pain was coming and going and colicky in character. The boy did not vomit, the bowels were rather loose. He looked pale; there were a few submandibular lymph nodes and on deep palpation a tender mass could be felt deep in the right iliac fossa.

Survey films of the abdomen are shown in Fig 3. A large lymph node was seen in left lateral recumbency. The child was discharged home the following day. Occult blood which was present on admission persisted for 14 days and full recovery took one month.

Case 4 Boy aged 4 years who 4 days before admission began to have abdominal pain which became worse during the last 24 hours. The pain lasted a few seconds; he screamed out with pain and doubled up. Clinical examination revealed a soft abdomen and a palpable descending colon but no masses were felt. The boy was kept under observation for 24 hours; he was still having central abdominal colicky pain, vomited once and had faeces in rectum. Intussusception was thought probable.

Films taken in supine and erect positions were unremarkable. The roentgenogram obtained in left lateral recumbency is presented in Fig 4. The colonic gas had shifted into the proximal colon, the caecal pole was filled with gas, which rendered intussusception unlikely. The gas in the caecum and ascending colon partly overlapped and was partly indented by rounded soft tissue masses. No treatment was given, apart from mild laxatives. The boy's condition improved and he was discharged home after 48 hours.

Case 5 Boy, aged 1 year and 9 months, who had been well until the morning of admission. During the day he had repeated attacks of abdominal pain which doubled him up and which were followed by vomiting. He had no diarrhoea but refused to eat. The boy was crying and was apprehensive during the examination, he had a soft abdomen and a doubtful mass of glands in the right iliac fossa and his temperature was raised. The roentgen film in supine position was of no interest. In left lateral recumbency the colonic gas shifted into the proximal colon. Several enlarged lymph nodes were observed which were partly encroached upon and partly overlapped by the gas in the caecum and the ascending colon (Fig 5).

Discussions

The author's first observation was made in 1953 (see Case 1). In the subsequent years there was an average of 4 to 5 cases per year. Each patient was referred under the clinical suspicion of intussusception and the diagnosis of mesenteric adenitis was made primarily on the basis of survey films of the abdomen. The diagnosis in each case was then discussed with the clinicians and if any doubt remained a diagnostic barium enema was performed. The need for the latter became smaller as the clinicians gained confidence in the radiographic diagnosis but it is still of the order of one in six. It is greater in those cases in which the radiographic diagnosis is based merely on the negative signs of mesenteric adenitis, i.e. those excluding intussusception, than in those which give positive proof of enlarged lymph nodes.

No case of intussusception was missed but there was one child, aged 11 months, in whom a diagnostic error might have occurred. An ileo caecal intussusception had progressed to the hepatic flexure without invaginating the caecum. The intussusceptum formed a finger-thick filling defect in a wide caecum and ascending colon which were fully distended by gas. Another child, aged one and a half years, was diagnosed as mesenteric adenitis and treated expectantly. A month later he was re-admitted with the typical picture of intussusception. At the subsequent operation both conditions were found to co-exist.

All cases had in common that there was either a pyrexial upper respiratory illness 5 days to 2 weeks before onset of abdominal pain or that other members of the family had febrile colds, pharyngitis or malaise during the preceding period. Stool examinations by culture were done as a routine but in none of the cases were pathogenic bacteria found. The cases occur when adenovirus in-

fections are common. Virus studies were made in the hospital population at the relevant time, in some of the cases diagnosed as mesenteric adenitis and in some of the contacts, they showed increased incidence of adenovirus types 1, 2 and 5.

SUMMARY

The radiographic appearances of acute non specific mesenteric adenitis are presented and the differential diagnosis with particular reference to intussusception is discussed.

ZUSAMMENFASSUNG

Die roentgenologische Erscheinungen bei akuter nicht spezifischer Mesenterial Drüsenentzündung werden beschrieben und die Differentialdiagnose besonders mit Hinsicht auf Intussusception wird diskutiert.

RÉSUMÉ

Description des aspects radiographiques de l'adenite mesentérique aigue non spécifique et discussion du diagnostic différentiel, en particulier avec l'invagination intestinale de l'enfant.

REFERENCES

- AYRD I. Acute non specific mesenteric lymphadenitis. Brit med J 1945 II, p 680.
- BELL T M and STEYN J H. Viruses in lymph nodes in children with mesenteric adenitis. Brit med J 1962 II, p 700.
- FRIMANN DAHL J. Roentgen examinations in acute abdominal diseases. Charles C Thomas, Springfield, Illinois 1951.
- GARDNER P S, KNOX G E, COLT S D M and GREEN C A. Virus infection and intussusception in childhood. Brit med J 1962 II, p 697.
- HAYDU N. Plain radiography of the abdomen in paediatric practice. Part II. Brit J Radiol 28 (1955) 597.
- HELLMER H. Intussusception in children. Diagnosis and therapy with barium enema. Acta radiol (1948) Suppl. No 65.
- JONES P F. Acute abdominal pain in childhood, with special reference to cases not due to appendicitis. Brit med J 1969 I, p 284.
- KJELLEN L. Studies on an unidentified group of cytopathic agents. Arch ges Virusforsch 6 (1955) 45.
- , STERNER G and SVEDMYR A. On the occurrence of adenoviruses in Sweden. Acta paediat (Uppsala) 46 (1957), 164.
- MIDDLEBURY J. Intussusception. Brit med J 1961.
- ROSS J. Intussusception. Brit med J 1961.
- SCHATZKI R. The roentgenologic appearance of intussuscepted tumours of the colon with or without barium examination. Amer J Roentgenol 41 (1939), 549.

HISTOLOGIC STAINING OF CONTRAST-FILLED BLOOD VESSELS IN MICROANGIOGRAPHED TISSUES

by

MARTTI KORMANO

Microangiography is valuable in research and has been recently used to an increasing extent. It is usually performed by filling the microvascular system of tissues with a fine-grained barium sulphate suspension.

Histologic preparations from tissues that have been microangiographed enable routine histologic studies of the material to be made. Microradiography and histology together afford valuable information on the relationship between microscopic structures and the appearances of the capillary bed in the microangiogram. Unfortunately, identification of all capillaries is not achieved by the standard microangiographic methods now available (LUNDSKOG, BRÄNEMARK & LINDSTROM 1968). Although microradiograms well depict the filled vessels, even three-dimensionally (BEJTMAN 1953), only a rough estimate of the number and location of unfilled vessels is obtained. A histologic study is often helpful although careful examination of the distribution of filled capillaries is laborious because of the low contrast of barium sulphate grains in small capillary cross-sections. Certain routine histologic staining methods were therefore tried for identification of small filled blood vessels in microangiographed tissues of the testis and epididymis. Histochemical methods used for indicating acid mucopolysaccharides were also studied.

Submitted for publication 27 March 1969

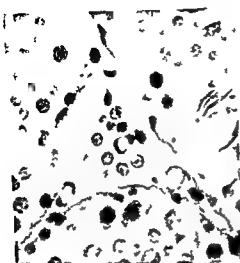


Fig 1 Haematoxylin-eosin staining of a 10 μ section of a microangiographed rat testis. The barium sulphate in the capillaries is unstained $\times 800$

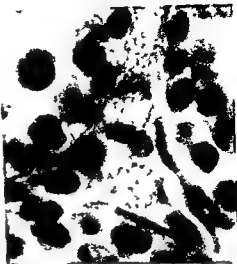


Fig 2 Haematoxylin-eosin staining of section of microangiographed 20 day-old rat testis. Filled capillaries visible with high power objective due to birefringent properties of barium sulphate grains $\times 2080$



Fig 3 PAS haematoxylin staining of adult rat testis. The barium sulphate in the capillaries is weakly purple although this does not call forth the pattern of the filled capillaries $\times 80$



Fig 4 The same testis as in fig 3 but the section was stained with 0.5% Alcian blue at pH 2.6 for 10 minutes. Filled blood vessels are intensely stained and some stain also in the testis tissue $\times 80$



Fig. 5. A 10 μ testis section stained with 0.1 % Alcian blue at pH 2.6 for 10 minutes. a) The filled blood vessels are selectively stained $\times 80$. b) Detail of (a). The staining of contrast medium in the capillaries is intense as compared with the background $\times 120$.

Material and Methods Male Sprague-Dawley rats were injected with barium sulphate 10 % (Micropaque, Damanco & Co Ltd). The injection and tissue processing were performed according to the standard procedure described in detail elsewhere (KORMANO 1967, 1968), using 4 % buffered formaldehyde for fixation. After paraffin embedding, 10 μ histologic sections were cut from the testes and epididymides and stained by the following methods: haematoxylin-eosin, periodic acid-Schiff-haematoxylin, Weigert-van Gieson, Cresyl violet, Bodian's silver impregnation, toluidine blue, Astrablau and Alcian blue. The relative differential staining intensity of the tissue and barium sulphate grains was studied microscopically.

Results

The barium sulphate granules remained unstained in the haematoxylin-eosin sections (Fig. 1). Identification of blood vessels down to arteriolar size was easy but capillary filling was often difficult to confirm. The location of the contrast medium had to be identified with a high-power objective and by taking advantage of the birefringent properties of Micropaque granules (Fig. 2). A low-power objective failed to reveal clearly the number and distribution of filled capillaries in a tissue section. On the other hand, an oil immersion objective



Fig 6 PAS haematoxylin staining of section of microangiographed rat epididymis. Only the largest blood vessels are easily identifiable. $\times 210$



Fig 7 Alcian blue 0.1% staining at pH 2.6 for 10 minutes of section of same organ as in fig 6. The smallest filled capillaries are identifiable. $\times 210$

indicated that the microscopic structure of the capillary walls was well preserved and easily identifiable.

The periodic acid Schiff method stained the barium sulphate granules weakly purple (Fig 3). The staining intensity was however low and generally less than that of the surrounding tissue. Identification of the pattern of filled capillaries was therefore less easy than in HE-stained sections. Blood vessel walls were sharply defined and the weak staining of the contrast medium did not interfere with the high-power observation.

Weigert van Gieson stain, especially suitable for connective tissue components within vascular walls, failed to stain the barium sulphate. No staining or any other advantage was obtained by using Cresyl violet, Toluidine blue or Bodian's silver impregnation. Astrablau staining for 10 to 30 minutes with 0.1 or 0.5% at pH 0.2 to 10.0 enabled a differentiation to be made between the barium sulphate grains and the tissue. However, the strong blue staining of mast cell granules (Bloom & Kelly 1960) and, on the other hand, variable intensity of the staining of the contrast medium was found to limit the value of this stain as a method of detecting filled capillaries.

In preliminary experiments, 0.5% Alcian blue (Alcian blue 8GX, Allied Chemical, Lot No 0365218, C 1 No 74240), stained the Micropaque granules

within blood vessels blue (Fig. 4). Epithelial cells of the epididymis and the contents of the epididymal duct were also heavily stained as compared with other cells. Because Alcian blue staining was the most promising of the techniques tested, its properties were examined more closely at different pH values from 2.6 to 10.0 and dye concentrations of 0.1 and 0.5 % of the staining bath. The tissue was intensely and diffusely stained with 0.5 % Alcian blue. The relative staining intensity of the barium sulphate grains also increased in the alkaline range but diffuse staining disturbed the differentiation between the content of the blood vessels and the tissue. At pH 2.6, little diffusion of the stain occurred but staining of tissue still occurred. The stain had some affinity to the walls of the blood vessels, and this in connection with the relative unsharpness of the general colour level rendered greater magnifications impracticable. Alcian blue staining at acid pH proved however a practicable means of detecting all the filled blood vessels, independent of size. By reducing the dye concentration to 0.1 % at pH 2.6, selective staining of a barium sulphate-filled vascular bed was obtained (Fig. 5). A time of 10 minutes was found to be sufficient, longer times causing greater colouring of the background.

This procedure was found to result in selective staining of barium sulphate grains in testis tissue (Fig. 5a) and a very good differentiation of filled epididymal blood vessels was achieved in spite of staining of the epididymal duct epithelium (Figs 6 and 7).

Discussion

The weak contrast of the barium sulphate grains in histologic sections is not a disadvantage for it does not disturb the general study of cellular structures. This may be the good if extravasation is apt to occur, as is often the case in microradiography of pathologic tissues (RUMIN 1966). However, if the number of filled capillaries, or the general capillary density of the microradiographed specimen are to be studied, detection of the small undiluted branches may be difficult. An attempt was made to overcome this disadvantage by adding Indian ink to the barium sulphate suspension (KARPPINEN & MÄLLARINEN 1967). This addition led however to a poor microscopic demonstration of the innermost layers of the blood vessels, and it may in case of leakage completely destroy the histologic picture. The entry of Indian ink particles into a given capillary also does not necessarily mean that the lumen is filled by the contrast medium, as the latter has a different particle size and a higher specific gravity. The method of specific staining of barium-filled blood vessels would therefore seem to be ideal for this kind of work.

Alcian blue, a cationic or 'basic', orthochromatic copper phthalocyanine dye,

groups (SINGER 1952, SCOTT, in the barium sulphate particles medium easily distinguishable

WAGNER & SHAPIRO (1957) have demonstrated that an obvious loss of polysaccharide specificity of Alcian blue occurs at as low a pH as 2.8. In spite of the staining of the barium sulphate even at higher pH ranges, the increase in background staining in the present application of the method also proved disturbing. The result seems to some extent to depend on the type of fixation. Staining with Alcian blue fails to meet the needs of a careful histologic examination of the tissue itself. It is however a simple and practicable method to use with routine staining procedures when information on the extent and localisation of capillary filling is required in microangiographed tissue embedded in paraffin.

Acknowledgement

The investigation was aided by a grant from the P. O. Klingenstein Foundation.

SUMMARY

The staining characteristics of intravascular barium sulphate grains were studied in histological sections. Alcian blue was found to stain the barium sulphate grains selectively and intensely.

ZUSAMMENFASSUNG

Es wurden Versuche angestellt um die Farberbereitschaft von Bariumsulfatkorncchen in histologischen Schnitten hervorstechen.

RÉSUMÉ

Les caractéristiques de coloration des grains de sulfate de baryum intravasculaires ont été étudiées sur des coupes histologiques de tissus microangiographiques. Le bleu alcian colore sélectivement les granules de sulfate de baryum dans les tissus fixés en formoline et inclus en paraffine et se teint intensément pour faciliter l'identification des structures microvasculaires injectées.

REFERENCES

- BELLMAN S. Microangiography. Acta radiol. (1953) Suppl. No. 102.
 BLOOM G. and KELLY J. W. The copper phthalocyanine dye 'Astrablau' and its staining properties especially the staining of mast cells. Histochemie 2 (1960), 48.
 KARPPINEN V. and MYLLÄRINEN H. A simple method of angio- and histoangiography. Ann. Med. exp. Fenn. 45 (1967) 94.

- KORMANO M • An angiographic study of the testicular vasculature in the postnatal rat 7
Anat Entwickl-Gesch 126 (1967), 138
- Microvascular structure of the rat epididymis Ann Med exp Fenn 46 (1968), 113
- LUNDSKOG J, BRÄNFMARK P-I and LINDSTRÖM J • Biomicroscopic evaluation of microangiographic methods In Advances in Microcirc Karger, Basel/New York 1968
- RUBIN P • Microcirculation of tumours I Anatomy, function and necrosis Clin Radiol 17 (1966), 220
- SCOTT J E, QUINTARELLI G and DE LUOVO M C The chemical and histochemical properties of Alcian blue I The mechanism of Alcian blue staining Histochemie 4 (1964), 73
- SINGER M Factors which control the staining of tissue sections with acid and basic dyes Int Rev Cytol 1 (1952), 211
- WAGNER B M and SHAPIRO S H Application of Alcian blue as a histochemical method Lab Invest 6 (1957), 172

ANGIOGRAPHIC DEMONSTRATION OF RUPTURE OF THE SPLEEN

by

BO LUNDSTROM

Clinical diagnosis of rupture of the spleen may often entail considerable difficulties. As a number of publications during the last decade have indicated the value of angiography to support this diagnosis there would appear to be good reason for reporting two cases in which the angiographic findings deviated somewhat from those previously published.

The first case of splenic rupture diagnosed angiographically was published in 1957 by NORELL who injected contrast medium into the aorta by means of a catheter inserted via the femoral artery. ÖDMAN seems to have been the first to use selective angiography of the coeliac artery for diagnosing rupture of the spleen. OLIN & ELMAN were early in publishing three cases angiographically diagnosed, all with operative verification. Accounts of a few cases have been given by BOIJSEN & OLIN, POLLARD et coll., NEBESAR et coll., BAUM et coll. and ROSCH. In these earlier publications, avascular areas in the spleen caused by the rupture itself or an associated haematoma, were given as the most important angiographic findings. BAUM et coll. also observed rapid circulation.

A larger number of cases examined angiographically of splenic rupture have

Submitted for publication 7 May 1969



Fig 1 Normal splenic angiography of the arterial phase (a), and the venous phase (b)

been reported during the last two years (AAKHUS & ENGÉ, LOVE et coll, BERK & WHOLEY). These support the view that the detection of avascular areas surrounded by displaced vessels represents an important diagnostic finding, even if it is not constant. The most typical angiographically demonstrable change would seem to be an accumulation of contrast medium in small extravasations with blurred definition. BERK & WHOLEY intimated that this 'mottled effect' might be due to aggregation of contrast medium in the sinusoids of the spleen. This was noted by AAKHUS & ENGÉ and by LOVE et coll as well as by BERK & WHOLEY in 37 of their combined total of 42 cases. In these three publications, rapid circulation (i.e. the veins soon become filled with contrast medium) was said to be common and angiographically demonstrable in a good half of the cases (24 out of 42 cases). FONTAINE et coll published 6 cases with operative verification. The angiographic findings were, however, not analysed in detail in their paper.

It has long been known that cystic cavities may appear in the spleen after rupture but no filling of such cysts in the course of angiography seems to have been described. No case has been published of a false positive or a false negative diagnosis of splenic rupture at angiography with the typical findings mentioned above.

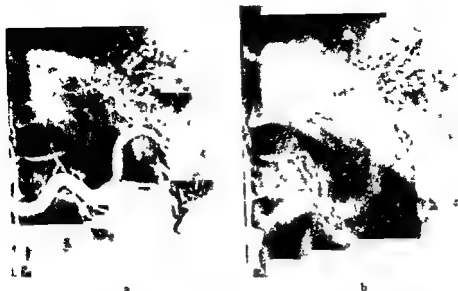


Fig 2 Rupture of the spleen (Case 1) in the arterial phase (a) and early venous phase (b). Numerous small extravasations in the supply area of the upper arterial branch, the splenic veins are filled sooner from the upper than from the lower part of the spleen, no angiographic changes in the lower pole.

Case reports

Case 1 A 19 year old woman, previously healthy, fainted some hours after moderate trauma to the left lower part of the thorax but was without symptoms after 24 hours. Pain partly of an intermittent nature, first appeared in the right lower abdomen. The patient was admitted four days after the accident. Her general condition was good, there was tenderness to palpation partly in the right lower abdomen and partly under the left rib arch. Haemoglobin 9.9 g/l, white blood corpuscles 5300/mm³ and blood pressure 140/80. Survey films of the abdomen disclosed a moderate amount of free fluid but otherwise no changes. Since the possibility of rupture of the spleen could not be excluded, selective angiography of the coeliac artery was performed.

Angiography (Fig 2) showed the splenic artery to be divided into two main branches. The supply area of the lower branch was normal (cf Fig 1). The arteries in the supply area of the other branch were somewhat stretched. The parenchyma of this part of the spleen was irregularly contrast filled and a large number of small irregular cavities were contrast filled. The filling of the veins occurred somewhat earlier from the upper part than from the lower part of the spleen. The radiologic diagnosis was rupture of the spleen.

Laparotomy revealed more than half a litre of blood in the abdominal cavity. There was longitudinal rupture of the spleen from the hilum towards its upper pole. Histologic examination of the spleen demonstrated haemorrhages in connection with the rupture but otherwise no changes.



Fig 3 Rupture of the spleen (Case 2), in the arterial phase (a) and the venous phase (b). Several cavities in the upper part of the spleen are filled and emptied at different rates with early venous filling from one of them (\rightarrow), an avascular area is present in the ventral part of the spleen, no angiographic changes in the lower pole

Case 2 A 23-year-old man, previously healthy, was admitted following a traffic accident with bone fractures and concussion. On the patient's arrival, when he was fully conscious, no abdominal symptoms were noted. After several days the patient began to complain of atypical pain in the left side of the abdomen, this was partly intermittent in nature and was aggravated by coughing, urination and defecation. The symptoms gradually increased, and three weeks after the injury increased tenderness to palpation under the left rib arch was noted. Some days later selective angiography of the coeliac artery was carried out to eliminate splenic rupture of the spleen.

Angiography (Fig 3), which was performed 26 days after the trauma, showed no changes in the lower third of the spleen (cf Fig 1), in other parts of the spleen the larger arterial branches were normal in appearance. The contours of the parenchyma were irregular and noticeably less dense in the upper part of the spleen than in the lower pole. Several large, well-defined cavities in the upper and central parts of the spleen filled at different rates, and emptied at different times. A vein leading from one of these cavities filled in the early arterial phase. A large avascular area lay in the central region. The radiologic diagnosis was splenic rupture.

Laparotomy disclosed half a litre of stale blood in the abdominal cavity. The spleen was enlarged with a longitudinal rupture laterally. One large and several smaller subcapsular haematomas were present. Splenectomy was performed. The histologic examination indicated partly healed rupture of the spleen and several haematomas and parenchymal necroses. No other changes were observed.

Discussion

The some 70 cases of angiographically diagnosed cases of rupture of the spleen so far published have provided certain valuable diagnostic criteria. As far as can be judged, the most constant pathognomonic finding is the demonstration of numerous small irregular extravasations. This sign has been observed in practically all cases where angiography has been carried out less than 4 days after the trauma, but has been absent in the few cases with older ruptures. Other important angiographically demonstrable signs of rupture are rapid circulation and the presence of avascular areas.

Rapid circulation was observed in some part of the spleen in the two present cases. Different parts of the spleen had completely different angiographic appearances but in each case the caudal part of the spleen was angiographically normal.

Small irregular extravasations of contrast medium of the type previously described were observed in the cranial part of the spleen in Case 1. LOVE *et coll* have published a similar case. The spleen is divided into two arterial supply areas between which there are no anastomoses: a larger upper anterior part and a smaller lower posterior part. It would seem reasonable to assume that only the upper anterior part of the spleen was involved in the rupture in Case 1, and was the reason for the different angiographic appearances in the two parts of the organ. Large well-defined cavities in the upper part of the spleen were filled in Case 2 and from some of these the contrast medium passed quickly into the veins as in arterio-venous aneurysms. No similar case has previously been published. It is likely that only the cranial part of the spleen was involved in the rupture in the present case.

Addendum in proofs

Another case, similar to Case 2, has been observed since the preparation of the manuscript. Angiography of the coeliac artery was performed in a 43 year-old man with multiple injuries a few hours after trauma. Some irregular cavities in the upper part of the spleen were contrast filled, from these cavities the splenic vein filled in the early arterial phase. The appearance was similar to traumatic arterio-venous fistulas elsewhere in the body, there was no mottling. A large splenic rupture in the upper part of the spleen was seen at operation.

SUMMARY

the
the

seen described as typical of rupture

from
from

ZUSAMMENFASSUNG

Es wird über zwei Fälle von angiographischer Diagnose von Milzruptur berichtet. Neben den bekannten Zeichen der Milzruptur zeigten beide Fälle Varianten der bisher wohl bekannten angiographischen Befunde.

RÉSUMÉ

Présentation de deux cas de rupture de la rate diagnostiquée par angiographie. Ces deux cas présentent des signes angiographiques assez différents de ceux qui ont été décrits comme typiques de la rupture de la rate.

REFERENCES

- AAJAHUS J and ENCI J: Angiography in traumatic rupture of the spleen. *Brit J Radiol* 40 (1967) 855
- BAUM S, NUSBAUM M, BLAKEMORE W S and FINKELSTEIN A K: Preoperative radiographic demonstration of intraperitoneal bleeding from undetermined sites by percutaneous selective celiac and superior mesenteric arteriography. *Surgery* 58 (1965), 797
- ROY R, FINKELSTEIN A K and BLAKEMORE W S: Clinical application of selective celiac and superior mesenteric arteriography. *Radiology* 84 (1965) 279
- BERK R N and WHOLRY M H: The application of splenic arteriography in the diagnosis of rupture of the spleen. *Amer J Roentgenol* 104 (1968) 662
- BOIJSEY E and OLIN J: Zoliakographie und Angiographie der Arteria mesenterica superior. Ergebnisse der medizinischen Strahlungsforschung. Georg Thieme Verlag Stuttgart 1964
- FONTAINE R, PIETRI J, JAPY C et coll: L'angiographie sélective dans le diagnostic des traumatismes fermés de la rate. *J Chir* 95 (1968) 587
- LOVE L, GREENFIELD G B, BRAUN T W et coll: Arteriography of splenic trauma. *Radiology* 91 (1968) 96
- NREBSAR R A, POLLARD J J, EDMUNDS JR L H and MCKHANN C F: Indications for selective celiac and superior mesenteric angiography: experience with 128 cases. *Amer J Roentgenol* 92 (1964) 1100
- NORELL H G: Traumatic rupture of the spleen diagnosed by abdominal aortography. Report of a case. *Acta radiol* 48 (1957) 449
- ÖDMAN P: Percutaneous selective angiography of the coeliac artery. *Acta radiol* (1958) Suppl No 159
- OLIN T och EKMAN C A: Coeliacografi som diagnostiskt hjälpmedel i kirurgin. (In Swedish) *Nord Med* 66 (1961) 1512
- POLLARD J J and NREBSAR R A: Splenic rupture demonstrated by selective splenic arteriogram. *J Amer med Ass* 187 (1964) 944
- ROSCH J: Roentgenologic possibilities in spleen diagnosis. *Amer J Roentgenol* 94 (1965), 453

EFFECT ON ERYTHROCYTES OF LARGE DOSES OF CONTRAST MEDIUM IN CLINICAL ANGIOCARDIOGRAPHY

by

LARS BJÖRK

Evidence has gathered through the years that a large part of the side effects of modern contrast media is directly correlated to the hyperosmolarity of these products. As the red blood cells are exposed to the highest concentration of the contrast medium on rapid intracardiac or aortic injection, these are obviously the cells that may be expected to incur damage, particularly on repeat examinations. It has been indicated that such damage occurs, by *in vitro* studies (BERNSTEIN et coll 1964, MCINTOSH et coll 1967) and in animal experiments (BERNSTEIN et coll). The aim of the present study has been to determine whether changes in the red blood cells may be demonstrated with standard laboratory methods, in patients in whom large quantities of highly concentrated contrast media had been injected at angiocardiology.

Material and Methods The material consisted of 10 routine cardiac patients six men and four women, aged between 41 and 56 years, subjected to angiocardiology as part of a pre operative evaluation for cardiac disease. Two were suffering from angina pectoris and the others had valvular heart disease.

Submitted for publication 19 June 1969

Unusually large quantities of contrast medium were needed in all the patients to arrive at a complete diagnosis. The dose varied between 3.0 and 3.7 ml per kg body weight, divided between four or five different injections during 20 to 30 minutes. All the injections were made into the left side of the heart or into the aorta. The speed of injection was approximately 30 ml per second and the contrast medium used was Isopaque 350 (sodium metrizoate balanced with calcium and magnesium ions, iodine content 350 mg/ml, Nyegård & Co A/S, Oslo).

Blood samples for the laboratory studies were drawn from catheters in the right atrium or pulmonary artery. Samples were obtained immediately before the first injection of contrast medium and within 60 seconds after the last injection. In addition, blood samples were obtained 24 hours after the angiocardio-graphic examination for determination of the haptoglobin. The following determinations were made in the blood samples obtained before and after angiocardio-graphy: (1) hematocrit, (2) plasma osmolality, (3) diameter of erythrocytes, (4) morphologic characteristics of erythrocytes, (5) osmotic resistance of red blood cells, (6) mechanical resistance of red blood cells, (7) potassium content of red blood cells, and (8) haptoglobin content of serum.

Results

A decrease in the hematocrit value after the angiocardio-graphies occurred in all patients, the average decrease being 16 % of the value obtained before angiocardio-graphy, with a range of 10 to 27 %. A slight but significant increase in plasma osmolality was also recorded after angiocardio-graphy. No change could be observed in the diameter of the red blood cells, or in the mechanical or osmotic resistance of the blood cells after angiocardio-graphy when compared with the values before angiocardio-graphy.

The number of cells with crenation was slightly increased after angiocardio-graphy in two patients. No other morphologic changes were present. Also the potassium content of the blood cells was unchanged. No significant change in the haptoglobin values before angiocardio-graphy and 24 hours after angiocardio-graphy were observed.

Discussion

With the exception of the slight increase in crenation of the red blood cells observed in two patients, the methods used in the study failed to disclose any acute or permanent damage to the red blood cells, even after injection of rel-

atively large quantities of contrast medium for angiocardiology. This is contrary to the findings of McINTOSH *et coll*. In the *in vitro* experiments, in which blood was exposed to a constant concentration of contrast medium, BERNSTEIN *et coll* observed a decrease in the red blood cell diameter, and morphologic changes in the red blood cells, both by animal experiments and *in vitro* tests with Biligradin in 'clinical doses, *in vitro* tests with Hypaque produced however no or only minimal changes.

An increase in the serum potassium, concomitant with a rapid decrease in hematocrit, was reported by McINTOSH *et coll* after aortic injection of Isopaque 440. In the present investigation, no evidence of loss of potassium from the erythrocytes was found. It therefore seems likely that if loss of potassium from the erythrocytes, sufficient to explain the increase in serum recorded by McINTOSH *et coll*, occurs, it must be a reversible process or the potassium must be released from other cells.

A considerable decrease in hematocrit occurred in all the patients, without any corresponding decrease in the red cell diameter, and with minimal changes in the morphologic appearances of the red blood cells in only two of the ten patients. This means that shrinking of the erythrocytes is probably responsible only for a minor part of the change in hematocrit observed at the same time. Migration of fluid from other cells or from extravascular spaces is probably largely responsible for the decrease in hematocrit.

The concept that cardiography with the technique now presented fails to give rise to permanent damage to the red blood cells is in agreement with the clinical observation that hardly ever signs of hemolysis occur after angiocardiology. This is also confirmed by the spectrophotometric studies of plasma in which no evidence of hemolysis was found (KLOSTER *et coll* 1966). On the other hand, hemolysis was recently reported in three patients following angiography (COHEN *et coll* 1969). Cholegradin *in vitro* gave an increase both in haptoglobin and free hemoglobin, whereas Hypaque produced no definite changes (BERNSTEIN *et coll*).

The results of the study would appear to indicate that the red blood cells are resistant to damage by highly concentrated contrast media even when injected repeatedly in large quantities. However, the methods used possess sources of error and may be too insensitive to reveal minor changes. The possibility must also be considered that damaged erythrocytes may have been removed from the blood or pooled, and consequently may not have reached the sampling site. Acute changes occurring during the first seconds after injection, when the concentration of contrast medium in the blood is high, may have been overlooked in the study. If such acute changes occur, they must be transient and fail to produce any appreciable permanent damage.

SUMMARY

The diameter, morphology, osmotic resistance, mechanical resistance and potassium content of the red blood cells as well as the haptoglobin content of the serum were studied in ten patients before and after angiocardiology with large doses of contrast medium. No differences were recorded with the exception of a slight increase in the number of crenated red cells in two patients.

ZUSAMMENFASSUNG

An zehn Patienten, die erhebliche Dosen von Kontrastmittel während angiographischen Untersuchungen erhalten hatten, wurden die Erythrocyten bezüglich ihres Durchmessers, ihrer Morphologie, ihrer osmotischen und mechanischen Resistenz sowie ihres Kaliumgehaltes vor und nach der Injektion überprüft. Es zeigten sich keinerlei bedeutsame Unterschiede, nur die Anzahl von Zellen mit gezinkten Rändern war in zwei Fällen leicht vermehrt.

RÉSUMÉ

I mmeur a étudié le diamètre, la morphologie, la résistance osmotique, la résistance mécanique et la teneur en potassium des érythrocytes ainsi que la teneur du sérum en haptoglobine chez 10 sujets avant et après angiocardigraphie faite avec de fortes doses de moyen de contraste. Il n'a pu noter de différence si ce n'est une légère élévation du nombre des érythrocytes crénelés chez deux sujets.

REFERENCES

- BERNSTEIN L, IVANS R L and SAITZMAN G F: Physico-chemical properties of blood following exposure to methylglucamine iodipamide, and other contrast media. *Acta radiol. Diagnosis* 2 (1961) 401.
- COHEN I S, KORRKO J P and WILLIAMS W H: Hemolysis and hemoglobinuria following angiography. *Radiology* 92 (1969), 329.
- KLOSTER F E, BRISTOW J D, JACONS W R et coll: Hemodynamic effects of angiocardiology. *Invest. Radiol.* 1 (1966) 298.
- McINTOSH H D, HURST V W, THOMPSON JR H K et coll: The hemodynamic effects of the injection of contrast medium (Isopaque). *Angiology* 18 (1967) 306.

Book reviews

CEREBRAL ANGIOGRAPHY By H Krayenbuhl and M Yargil 401 pages and 524 illustrations Butterworths, London 1968 Price 18 £ III Sh

The second edition of this well known textbook on cerebral angiography has been translated into the English language with the text revised and newly gained experiences incorporated. As in the original German edition the illustrations are excellent and their number is overwhelming.

A chapter deals with the authors' technique for angiography. Contrary to the practice of the reviewer the authors recommend puncture of the common carotid artery as a normal procedure and selective puncture for special purposes; they favour direct puncture of the vertebral artery.

A comprehensive and extensive survey of the anatomy of the cerebral vessels and their normal variations is most valuable and occupies nearly a quarter of the book. Some of the work deals with the angiographic signs in space-occupying lesions which have been divided into non-specific displacement syndromes and specific localization syndromes. Displacement syndromes are tabulated and discussed from pathologic and angiographic viewpoints, various forms of herniations and localizations of expanding lesions being differentiated. The topographic diagnosis of supra- and infratentorial tumours are considered in a special chapter, copiously illustrated with roentgen films as well as drawings.

The authors emphasize that the pathologic diagnosis of intracranial tumours is best made by serial angiography in which the vascularity of the mass as well as the disturbed circulation within the tumour can be studied. The differences in appearance between gliomas, meningiomas and metastatic tumours are well documented and angiographic signs separating different forms of gliomas, as well as detailed investigation of meningiomas, are described. Disturbances in the circulation as evident from cerebral angiography, not only in connection with different kinds of tumour but also as a part of disease of the cerebral vessels are discussed. Modern concepts of angiographic investigations of ischemic lesions are however given less attention than the classical aspects of angiography, i.e. tumours, malformations, traumatic incidences. A chapter deals with the physiology and pathology of the cerebral circulation and also includes remarks on collateral circulations in different conditions.

The book includes an extensive bibliography, the vast number of references being arranged in relation to each chapter but collected at the end of the book. There is also an authors' index as well as a reliable subject index, both of which should prove useful. The book represents a good reference source and should be valuable for looking up anatomical variations and anomalies and as well as for gathering information on expanding lesions and their locations within the brain.

Bengt Liliequist

ZONOGRAPHY—NARROW-ANGLE TOMOGRAPHY By D Westra 82 pages, 38 figures and 58 references Excerpta Medica Foundation, Amsterdam 1966 Price. 18 DFL

The term 'focal plane' is utilized for the tomographically produced image plane in the introductory chapter dealing with the fundamentals of tomography. This is unfortunate because the object and its projected 'space image' is always three-dimensional and the recording film can be arranged in any desired plane and orientation. The term 'focal plane' refers exclusively to optical systems in which at infinity, for instance, a focal plane exists. The existence of the 'space image' discussed by MARSTRANDER has been ignored.

It is claimed that narrow-angle tomography may give 'more information than ordinary tomography'. The information to be obtained from tomography is distributed in the numerous cuts, which must always be studied together. Three-dimensional topographic information will then be obtained. It is wrong to believe that a single tomogram constitutes an examination.

A narrow-angle tomogram is a compromise and may cover in a defective way what ordinary tomograms may provide. As the tomographic angle is varied continuously, films may be obtained down to those with no angle at all and a summarily fixed projection, the ordinary radiogram. Alteration of the tomographic motion pattern regarding shape and size produces varying tomographic effects. A reduction of the angle primarily means reduced tomographic effect so that the layers are in the form of a summation. A true tomogram representing one layer cannot be compared with one 'composed' of several layers.

The author overlooks the 'space image' and its immense number of possibilities in the fundamental description of tomography. The law of the tangent and the image formation is discussed with references to ZIEDESS DES PLANTES and EDHOLM. The expression 'focal depth' is introduced here and for reasons already mentioned ought to be avoided.

Misunderstanding in the presentation of points of difference is obvious. Different object borders cannot be demonstrated either by tomography or zonography. Tomography is a more selective method and zonography includes more detail, not different detail. Zonography is a superimposing of cross sections. The opinions about maximum acceptable unsharpness, discussed in the thirties, have not the same value today; modern apparatus is capable of producing well defined sections at 1 mm interspacing and a so-called layer thickness of the order of a tenth of a millimeter. These factors are of real importance as small objects are often of interest. The demonstration of sharpness and contrast of image borders would be clarified by a drawing. The experiments seem to have been made with unsuitable exposure conditions—the contrast being too low—and with a blackening indicating that the density curve would be nonlinear, a fact that might influence the conclusions. In hypocycloid motion the borders always have a characteristic tendency to form double or triple contours. This does not appear from the illustrative material and raises the question as to what factor has hidden it. The experimental presentation is somewhat confused. The expression 'integration density curve' is introduced to represent the 'shadow' of an object. This is another example of the unauthorized use of scientific expressions. Density curves (H and D curves) must be exclusively retained for densitometry in photography and radiography.

The definition of the tomographic image border including certain physiologic aspects and viewing distances are discussed and experiments with the latter for tomograms up to 5 meters are mentioned. The discussion based on EDHOLM's work ignores the role played by photographic factors. The author arrives at the conclusion that a free zone around the object is important and calculates its depth. Some applications are presented, e.g. to the thorax, tracheobronchial system, gallbladder and kidneys. Stereoscopy with zonography is mentioned.

DIAGNOSTIC RADIOLOGIC INSTRUMENTATION—MODULATION TRANSFER FUNCTION Edited by Robert D Moseley Jr and John H Rust 425 pages, 180 figures 23 tables and 155 references Charles C Thomas, Springfield Illinois 1965 Price 17 50 dollars

Great need exists for specification of methods for measurement of image quality. A colloquium on Diagnostic Radiologic Instrumentation was held at the University of Chicago, the proceedings of which form the content of this volume.

BOLWERS in presenting electronic equipment for recording contrast transfer, mentions photographic problems. He seems to accept the modulation transfer function principle although the photographic recording is nonlinear. INGELSTAM in the subsequent discussion touched upon non linearities in the intensifiers for electronic reasons which might produce difficulties in applying this linear theory. O'LOUGHLIN stressed the difficulties in applying modular transfer function to film screen combinations and mentioned that ROSSMAN has modified the problem and made a power spectrum, mathematically similar but dose dependent and producing other complications.

TODDENHAM considered visual physiology and instrumentation in roentgen diagnosis. MORGAN discussed problems connected with quantum fluctuations and visual perception. SCHÖBER applied the Shannons information theory to roentgen images, its value in radiology is limited. The extreme care that must be taken to avoid using it improperly is exemplified, it is only applicable to purely optical systems.

from the exposure

well with the image quality of intensifiers and treated all parts of the chain, vignetting and internal scatter are presented. MOSELEY, HOLM and WILLIAMS have made a study of various camera tubes. In the subsequent discussion ROSSMAN emphasized that true modular transfer function must be independent of noise and FOWLER stressed that the presentations are, because of noise not modulation transfer curves. GUYOT recorded a study of factors limiting resolution and contrast in intensifiers. MARHOFF and SCHOTT made an evaluation of the roent

ROSSMAN pointed out that it is much more valuable to compare Magnification in intensifiers was discussed by FEDDEMA and ZIEHLER compared various TV chains in clinical practice.

This collection of papers are of considerable value, their value is further increased by the discussions which to some extent may form a substitute for readers who did not attend the meeting.

Ove Mattsson

HISTORY AND DEVELOPMENT OF RADIOLOGY IN DENMARK 1896—1950 By P. Flemming Møller
530 pages and some twenty photos and figures. Nyt Nordisk Forlag Arnold Busck, Copenhagen 1968. Price 78.50 Dkr.

The physicians who first recognized the value of the new roentgen technique and attempted to bring it into use in medical practice encountered resistance and a sceptical attitude from fellow physicians. The author convincingly maintains that the odd and controversial character, J. Mjyge, must be regarded as the pioneer of Danish radiology. After this account the author in the following chapters may be said to have borrowed his method of describing the historic development from tomography, each layer being confined to a description of the events of one year. Thus the radiologic material published in Danish medical journals year by year, and consisting of original articles, reports on lectures read before Danish associations and notes on articles from foreign journals thus form the main source of the material. From the year 1921 material from *Acta Radiologica* naturally enough is also mentioned. The reports are carefully worked out and information is given regarding the page on which the original article appears in the relevant journal. By this method the author presents the historical material in the form of a structure in time in which the events of each individual year add up to make a whole. Brief isolated reviews of past events are given only occasionally. The foundation and development of the university training clinics for radiodiagnosis and radiotherapy and the creation and extension of teaching appointments are however dealt with in order.

This work presents an exhaustive survey of the radiologic development that has taken place in Denmark. A special complementary section containing concise accounts of the developments in the various fields of diagnosis (heart and lungs, alimentary tract, urinary tract, nervous system and so on) as well as of those in the field of radiotherapy in general would have added much to the interest. It should however be added that the reader has the possibility of obtaining such information for himself by utilizing the index in which the medical diagnoses and authors cited are included.

The book bears the mark of scrupulous attention to detail and in consequence has great documentary value as a retrospective account of the historical developments in medical radiology.

Folke Knutsson

KONTENDIAGNOSTIK DER ILIOSAKRALGELENKE UND IHRER NAHEN UMGEBUNG Von W. Döhlmann. 141 Abbildungen in 258 Einzeldarstellungen. Georg Thieme Verlag, Stuttgart 1967. Price 54 DM.

Different lesions of the sacroiliac joints play a dominant role in low back pain although only too often early diagnosis is overlooked because of inferior routine roentgen examination of the lumbar spine. Such an examination should always include adequate examination of the sacroiliac joints irrespective of the clinical request so that the examiner may recognise the normal variations and the early signs of pathologic processes.

It is therefore a pleasure to review this excellent book dealing with the sacroiliac joints. The anatomy and roentgenology of these joints are presented with excellent illustrations. A chapter dealing with malformations is followed by the main chapter on inflammatory lesions of the joints, naturally dominated by spondylitis ankylopoetica. This condition is

called peliospondylitis ossificans in Sweden which appears to be a more adequate term in the light of knowledge of the nature of the disease.

The reviewer cannot agree with the author on die nosologische Einordnung krankhafter Iliosakralbefunde, neither with the statement that osteitis condensans may occur in man. These comments do not however reflect upon the essential value of this important chapter from the view point of roentgen diagnosis thanks to detailed descriptions of both early and late lesions superbly illustrated with roentgen films and drawings. The chapter on degenerative changes is most instructive and the last chapter on expansive lesions in the iliosacral region is noteworthy for the manner in which the diagnostic difficulties are depicted.

The wide experience of the author is reflected in the text and the illustrations are of excellent quality and well chosen. The book can be warmly recommended.

Sen Iden

DAS RONTGENFERNSEHEN
DUNG By Prof. Dr. Alf

164 pages 92 figures

Price 34 DM

The two first mentioned authors are radiologists at the University of Frankfurt am Main the third being employed at the Siemens Scientific Laboratory. This will indicate the value of the presentation of this important subject.

Conventional fluoroscopy is discussed in relation to physiologic aspects and dosage. The construction of the image intensifier is described and its properties are discussed also the

are discussed the use of subtraction by electronic means as well as stereoscopic fluoroscopy with roentgen television, image storage systems and video tape recording are all included.

The use of television for various purposes in a roentgen department with arrangements to present current examinations to large audiences are exemplified. Various practical col

television in connection with pediatry, otolaryngology, gynaecology and roentgen therapy is briefly mentioned.

The extensive list of references (close to 300) increases the value of a book that has much to give to most radiologists.

Ole Mattsson

DYNAMIC FACTORS IN ROENTGEN DIAGNOSIS By Elliott C Lasser With a chapter by John H Feist and a foreword by Leo Rigler 356 pages, 134 figures Williams & Wilkins Company, Baltimore 1967 Price 12 75 dollars

Roentgen diagnosis in the early days was founded upon anatomy and pathology and depended upon the laws of physics and geometry that produced the roentgenogram It was *something static with little regard paid to dynamic factors* Conditions have changed, not at least by the introduction of new roentgen procedures as well as by a different way of analysing the information available from the films obtained

This book initially carried the title 'Physiologic Factors underlying Roentgen Anatomic Diagnosis' This has been rephrased to indicate that radiographic examinations present either active or completed processes A wider understanding of the close relation between the roentgen and various physiologic factors may be obtained from the appreciation of metabolic considerations, physiologic chemistry, effect of drugs and innervation and endocrine effects as well as secondary changes arising from anomalies and abnormalities in secretion Knowledge of an embryologic background leads to a better understanding of gross anomalies *Again the findings in a case of heart failure must be considered with due regard to the dynamic conditions*

The work is concentrated on certain organs The central nervous system and the urinary tract are discussed in separate chapters The effects of contrast media receive special attention and their development and chemistry are described The gastro intestinal tract is afforded considerable space, with references extending to some one hundred and twenty The basic physical and physiologic principles of the heart are considered with special reference to cardiac failure The evolution of congenital abnormalities is explained, pulmonary dynamics and kymographic methods are considered, and the biologic basis of bone roentgenology and bone metabolism is discussed in a simplified manner Diseases of bone are dealt with and attention paid to the mineral content of bone and its measurement An extensive and well illustrated differential diagnosis approach to bone changes forms an important part of the book

This work offers a valuable concentrated contribution to radiologic diagnostics of today where new aspects compared with conventional static principles are in the foreground It should prove particularly useful, say to radiologic trainees and to those engaged in teaching

Ole Mattsson

ANGIOGRAPHIC DIAGNOSIS OF TUMORS ARISING FROM THE PANCREATIC ISLETS

by

ERIK BOIJSEN and LARS SAMUELSSON

The first preoperative angiographic diagnosis of a pancreatic insulin producing tumor was reported by Olsson (1963). Since then, several reports on the value of selective angiography in the diagnosis of tumors of the islets of Langerhans have appeared.

The hormone-producing neoplasms of the pancreas are usually richly vascularized and accumulate contrast medium to a higher degree than the surrounding structures. Nevertheless they are frequently so small that they may escape detection even in high quality celiac and superior mesenteric angiograms. A small growth embedded in the parenchyma may also escape detection at operation. It is therefore of importance to establish whether a firm preoperative diagnosis of an islet cell tumor can be achieved with selective angiography.

Previous investigations Tumors of the islets of Langerhans usually produce hormones and four distinct syndromes may develop: (1) hyperinsulinism caused by beta cell tumor, (2) the Zollinger-Ellison syndrome caused by an overproduction of gastrin from a non beta cell tumor, (3) a severe form of diarrhoea with

From the R
Hospital Sv
Medical Res

nd University
the Swedish

May 1970

hypokalemia probably due to an unknown hormone from a non beta cell tumor, and (4) hyperglucagonism with diabetes caused by an alpha-cell tumor

Both alpha- and beta cell neoplasms may be present without concurrent hormonal production

There are reports in the literature of 35 patients with insulin producing tumors evaluated with selective angiography of the celiac or superior mesenteric arteries (OLSSON 1963, 1965, BAUM *et coll* 1965, BUONOCORE *et coll* 1965, ROSCH 1965, ROSCH & BRIT 1965, WENZ 1965, BOOKSTEIN & OBERMAN 1966, MADSEN 1966, MCCONNELL *et coll* 1966, OLIVIER *et coll* 1966, SCHIFFRIN & TALA 1966, VUORINEN & WEGFELS 1966, HERNANDEZ & HELFON 1967, NEBESAR & POLLARD 1967, VAN VOORTHUISEN 1967, LEONARDUZZI *et coll* 1968) Two patients had two tumors each and one patient had three tumors. Fourteen tumors were located in the head, four in the body, and fifteen in the tail of the pancreas. In five patients, each with one tumor, the site was not reported. In one patient, who had had a previous pancreatectomy, hyperinsulinism resulted from liver metastases demonstrated by angiography. Of the 33 operated tumors, 22 were recognized at angiography. Of the 11 undetected growths, 2 were located in the head of the pancreas, 2 in the pancreatic body and 7 were present in the tail of the pancreas. One tumor was 2 mm in diameter while the remaining ten varied in size between 10 and 30 mm.

The twenty-two growths with positive angiographic findings were between 10 and 50 mm in size. BOOKSTEIN & OBERMAN were unable to identify five out of seven insulin-producing tumors and were of the opinion that only 20 % of these could be demonstrated by high quality selective angiography. MEANY & BUONOCORE (1965) and MADSEN (1968) noted on the other hand that even small histologically poorly vascularized beta cell tumors could be demonstrated by angiography.

Excluding the material of BOOKSTEIN & OBERMAN, thirty-two insulin producing tumors have been reported, twenty-five of which (80 %) were demonstrated at angiography. It must be emphasized that five of the seven growths of BOOKSTEIN & OBERMAN were situated in the tail of the pancreas, an unusual angiographic location for beta-cell tumors. In a large series insulin producing tumors occurred most frequently in the tail of the pancreas (BREDANIL *et coll* 1955).

Four malignant insulin-producing tumors, all with metastases were evaluated by angiography (OLSSON 1965, ROSCH & BRIT 1965, HERNANDEZ & HELFON 1967, MADSEN 1968). Two of the patients had richly vascularized metastases while small liver metastases were undetected in the other two patients.

Non beta islet cell tumors producing the Zollinger—Ellison syndrome have been identified by angiography in seven patients (BOIJSEN 1965, FONTAINE *et coll*

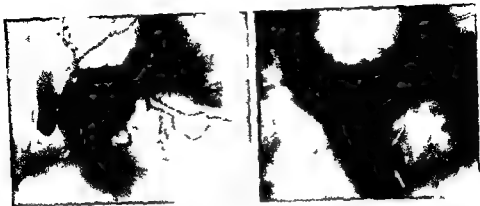


Fig 1 Benign insuloma of the tail of the pancreas in a 57 year-old woman. No growth was revealed at combined celiac and superior mesenteric angiography. At selective splenic angiography, however, a 1.5 cm tumor could be seen close to the tail of the pancreas (arrows). There is accumulation of contrast medium in the growth but no tumor vessels can be seen.

1965, LUDIN et coll 1966, CLEVETT & PARK 1967, HERNANDEZ & HILLEN 1967, THOMAS et coll 1968, ZBORALSKÉ & AMBERG 1968). In one of these, in whom pancreatic resection had been performed previously, local recurrence as well as metastases were observed. Five of the ulcerogenic tumors were malignant, with metastases of the same type of vascularization as the malignant insulin-producing tumors, i.e. small richly vascularized, nodular tumors. The primary growths, whether malignant or benign, were all richly vascularized.

One patient with a non beta cell malignant tumor and without the ulcer diathesis had profuse diarrhoea (GOULON et coll 1966). The Zollinger—Ellison syndrome may start with diarrhoea before the ulcerations appear. Here again the rich vascularization present in the other non beta cell tumors was observed.

Hyperglucagonism secondary to an alpha cell carcinoma has been observed in one patient, who had angiography for hepatic metastases (MCGAVRAN et coll 1966). In this patient the primary as well as the secondary tumors were highly vascular and therefore well demonstrated at angiography.

Non functioning islet cell carcinomas do occur (HESS 1946). Only three patients with a malignant inactive insuloma appear to have been studied angio-

graphically. In these patients, the metastases were also similar.

Previous findings at angiography of islet cell tumors have indicated that the malignant tumors are generally larger, have more abundant tumor vessels and are therefore better demonstrated than the benign beta or non beta cell tumors.

hypokalemia probably due to an unknown hormone from a non beta cell tumor, and (4) hyperglucagonism with diabetes caused by an alpha cell tumor

Both alpha and beta cell neoplasms may be present without concurrent hormonal production

There are reports in the literature of 35 patients with insulin producing tumors evaluated with selective angiography of the celiac or superior mesenteric arteries (OLSSON 1963, 1965, BAUM *et coll* 1965, BUONOCORE *et coll* 1965, ROSCH 1965, ROSCH & BRET 1965, WENZ 1965, BOOKSTEIN & OBERMAN 1966, MADSEN 1966, MCCONNELL *et coll* 1966, OLIVIER *et coll* 1966, SCHIFFRIN & TALA 1966, VUORINEN & WECHEUS 1966, HERNANDEZ & HEIFRON 1967, NEFFSAR & POLLARD 1967, VAN VOORTHUIZEN 1967, IERARDUZZI *et coll* 1968). Two patients had two tumors each and one patient had three tumors. Fourteen tumors were located in the head, four in the body, and fifteen in the tail of the pancreas. In five patients each with one tumor, the site was not reported. In one patient who had had a previous pancreatectomy, hyperinsulinism resulted from liver metastases demonstrated by angiography. Of the 33 operated tumors, 22 were recognized at angiography. Of the 11 undetected growths, 2 were located in the head of the pancreas, 2 in the pancreatic body and 7 were present in the tail of the pancreas. One tumor was 2 mm in diameter while the remaining ten varied in size between 10 and 30 mm.

The twenty two growths with positive angiographic findings were between 10 and 50 mm in size. BOOKSTEIN & OBERMAN were unable to identify five out of seven insulin producing tumors and were of the opinion that only 20% of the could be demonstrated by high quality selective angiography. MANSER & BUONOCORE (1965) and MADSEN (1968) noted on the other hand that even small histologically poorly vascularized beta cell tumors could be demonstrated by angiography.

Excluding the material of BOOKSTEIN & OBERMAN thirty two insulin producing tumors have been reported twenty five of which (80%) were demonstrated at angiography. It must be emphasized that five of the seven growths of BOOKSTEIN & OBERMAN were situated in the tail of the pancreas an unusual angiographic location for beta cell tumors. In a large series insulin producing tumors occurred most frequently in the tail of the pancreas. BREIDAHN *et coll* (1955)

Four malignant insulin producing tumors all with metastases were evaluated by angiography (OLSSON 1965, ROSCH & BRET 1965, HERNANDEZ & HEIFRON 1967, MADSEN 1968). Two of the patients had richly vascularized metastases while small liver metastases were undetected in the other two patients.

Non beta islet cell tumors producing the Zollinger-Elliott syndrome have been identified by angiography in seven patients (BOIJSEN 1965, FONTAINE *et coll*



Fig 3 Malignant intusussus of the duodenum and of the uncinate process of the pancreas in a 59 year old woman who had been diabetic for 17 years. Parium meal examination and subsequent celiac angiography disclosed a richly vascularized tumor of the duodenum. At superior mesenteric angiography however the same tumor as well as a second tumor in the uncinate pancreatic process were demonstrated. Displaced arteries, tumor vessels and dense accumulation of contrast medium in both tumors (arrows). There were no metastases.

celiac and superior mesenteric arteries while three patients had injections only into the celiac artery.

In the total of eighteen patients in whom selective angiography was performed, eight insulin producing tumors were observed in seven patients. Twelve of the patients were operated upon and one additional neoplasm was discovered in a patient in whom the angiographic examination was considered normal. In the six patients who were not operated upon the angiograms were negative and the symptoms were either too vague or could be ascribed to other causes.

Reevaluation of the angiographic series in the eight patients with insulin producing tumors gave the following results. The tumor not diagnosed prior to operation was a 30 mm carcinoma located in the tail of the pancreas. The angiograms, with combined injection into the celiac and superior mesenteric arteries were of moderately good quality and after subtraction in retrospect slight vascular abnormalities were observed. These were not however sufficient to establish a definite diagnosis. The tumor could probably have been diagnosed if injection of contrast medium had been made into the splenic or hepatic arteries but this method was not in practice at that time.

The remaining eight tumors were found prior to operation but on two occasions injection into the splenic and hepatic arteries was necessary to establish the diagnosis. In both these patients there was a definite clinical diagnosis of an



Fig 2 Benign insuloma of the head of the pancreas in a 58 year old woman a) No insuloma could be demonstrated at combined celiac and superior mesenteric angiography b) and c) A richly vascularized insuloma 50 mm in diameter was demonstrated at common hepatic angiography

Material and Results

Hyperinsulinism Eighteen patients had symptoms referable to an insulin producing tumor. Selective angiography was performed in all. In fourteen of the patients the contrast medium was injected simultaneously into the celiac and superior mesenteric arteries, and in two patients injection into the splenic and hepatic arteries was also performed. One patient had separate injections into the



Fig 5 Normal pancreas in a 51 year-old man who 30 years previously had undergone gastric resection and who for 2 years had been diabetic and had attacks of fainting. Combined celiac and superior mesenteric angiography disclosed a 3x by 20 mm tumor in the pancreatic tail (arrow). No local accumulation of contrast medium but tortuous vessels. Resection of the pancreatic tail revealed no tumor. The abnormal findings were related to the presence of collateral circulation from the left gastroduodenal artery following ligation of the right gastroduodenal at the earlier gastric resection.

One patient had a benign 20 mm neoplasm of the uncinate process, again exclusively supplied by the superior mesenteric artery (Fig 4). The tumor had the same angiographic characteristics as those previously mentioned. At operation it was neither seen nor palpated, but following incision of the pancreas in the area angiographically demonstrated to be abnormal, the growth became visible and was removed.

With one exception tumor vessels were observed in all patients with a preoperative diagnosis of insuloma. Their extent varied but was generally greater in growths more than 20 mm in diameter. Displacement of small pancreatic arteries was observed in six of the neoplasms. Accumulation of contrast medium always occurred, except in the lesion not diagnosed prior to operation. Venous drainage was observed in seven tumors. The largest growth in this series measured 50 mm in diameter and was benign. The three malignant tumors varied from 20 to 30 mm in diameter.

Four tumors were located in the tail of the pancreas and four in the head of the pancreas, which included two in the uncinate process and one tumor in the duodenum.

Resection of the pancreatic tail was performed in three patients who had local hypervascularization in this area at angiography but in whom no neoplasm was seen at microscopy. Gastric resection had been performed previously in one of these patients, and at angiography a local network of tortuous arteries gave the



Fig 4 Benign insulinoma of the uncinata process of the pancreas in a 58-year-old woman with typical signs of hyperinsulinism for 4 years. Combined celiac and superior mesenteric angiography revealed a 25 by 20 mm tumor, richly vascularized and containing a dense accumulation of contrast medium. The tumor at operation was found to lay in the abnormal area demonstrated at angiography.

insulin-producing tumor, and this was the indication for the further angiographic procedures. In one patient, the 15 by 10 mm tumor was demonstrated in the tail of the pancreas only after splenic artery injection. No tumor vessels could be seen but an intense and long-lasting accumulation of contrast medium was present. Even in retrospect the growth could not be identified in high-quality combined celiac and superior mesenteric angiography (Fig 1).

The second patient also had a combined injection into the celiac and superior mesenteric arteries but the arteries of the head of the pancreas were not demonstrated because of an anomalous origin of the common hepatic artery directly from the aorta. After selective injection of contrast medium into this artery, the complete blood supply of a 50 mm tumor was demonstrated (Fig 2).

Two malignant insulin-producing tumors were present in one patient. One was located in the duodenum and was demonstrated by a barium meal and celiac angiography, the second was present in the uncinata process and was first demonstrated by superior mesenteric angiography (Fig 3). Both growths were malignant and their respective diameters were 20 and 25 mm, they were highly vascularized and the accumulated contrast medium remained for a long time.

graphy. At operation, an 8 mm benign insuloma was extirpated from the body of the pancreas. Reviewing the angiographic series with the subtraction technique, a local accumulation of contrast medium was present in the body of the pancreas. No tumor vessels could be identified (Fig 7).

Nor functioning tumors of the pancreatic islets Three patients were referred for angiography because of general malaise in one patient and jaundice in the remaining two. There were no signs of endocrine activity but at operation malignant insulomas were revealed in all three patients. The growths were located in the head of the pancreas and were highly vascular. With the exception of more tumor vessels, the angiographic appearances regarding accumulation of contrast medium and venous drainage were similar to those in tumors with endocrine activity. All had metastases and these had the same characteristics as those possessing endocrine activity (Fig 8).

Discussion

Despite the fact that several series of patients with hyperinsulinism have now been reported, with tumors demonstrable by selective angiography, the question of accuracy is still unanswered. The experiences of BOOKSTEIN & OBERMAN suggest that angiography should be inadequate to diagnose insulin-producing tumors. The present angiographic series, in which eight of nine insulin producing tumors were demonstrated prior to operation, permits a more optimistic view of the diagnostic value of angiography in this disease. This is also in agreement with other communications, though it must be admitted that positive findings are more likely to be reported than false negatives.

An explanation for the difference in the results attained in the present series compared with those of BOOKSTEIN must be sought. The location of the lesion seems to be an important factor. Small tumors of the pancreatic tail may more easily escape detection. All the undemonstrated growths of BOOKSTEIN, larger than 10 mm in diameter, were present in the tail of the pancreas. With the same angiographic technique the present authors were unable to demonstrate two out of four neoplasms. Special injections in one of these patients produced the correct preoperative diagnosis. Thus, if combined celiac and superior mesenteric angiography fails to demonstrate an insuloma in a patient with typical symptoms and laboratory findings of hyperinsulinism, the diagnostic procedure should be complemented with injection into the splenic artery. There was reason to believe that the only growth that went undiagnosed in the series could have been demonstrated by the method. The improved quality obtained after injection into the splenic artery better demonstrates small pancreatic lesions (PALL JR et coll 1963, BORG



Fig 6 Normal pancreas in a 24 year old man who for 10 years had attacks ascribed to hyperinsulinism. Combined celiac and superior mesenteric angiography suggested insulinoma of the tail of the pancreas. At operation, however, the pancreatic tail was resected but proved to be normal. In retrospect the hypervascularization was due to the positioning of the tip of the catheter in the celiac artery from which a large amount of contrast medium was directed into the dorsal pancreatic artery.

impression of malignancy, in retrospect it seemed to be caused by a collateral circulation arising as a consequence of the resection (Fig 5). There was no local accumulation of contrast medium in the area where abnormal vessels were observed. The other two patients had a diffuse but marked accumulation of medium in the tail of the pancreas. This resulted from inadvertent positioning of a catheter tip in the dorsal pancreatic artery, diverting a large amount of medium to the body and tail of the pancreas and suggesting hypervascularization (Fig 6).

Non-beta-cell tumors with the Zollinger—Ellison syndrome Three patients were studied, one of whom has been reported previously (Boijesen 1965). At selective hepatic angiography there was a local recurrence of a highly vascular non-beta-cell tumor, the original tumor having been resected. Small nodular, richly vascularized metastases were present. One patient refused operation and the diagnosis of a 20 mm growth in the duodenal wall was thus not substantiated. The lesion was moderately vascularized and contained only a slight accumulation of contrast medium.

The third patient had severe epigastric pain and ulceration of the second part of the duodenum. The upper gastrointestinal examination suggested ulcerating carcinoma of the head of the pancreas but no tumor was observed at angio-

according to BREIDAHN et coll (1955), occur in 10 to 12 % of patients. One patient of the present series had two growths, one demonstrated by celiac angiography while the other became apparent only after superior mesenteric angiography.

It was not possible by angiographic means to differentiate between the various types of functioning growths. The same type of tumor vessels was observed in all except two small neoplasms, one insulin producing, and one ulcerogenic, in neither of which tumor vessels were observed. The non functioning islet cell growths had more abundant tumor vessels and were larger than the functioning neoplasms.

The long lasting accumulation of contrast medium in the tumors reported by OLSSON (1963) is a common occurrence but not always demonstrated. Films of high quality should reveal a local, well circumscribed accumulation of contrast medium. This is important to recognize in order to avoid a false positive diagnosis, as occurred with one of the patients in whom collateral vessels were thought to represent tumor vessels. Displacement of small pancreatic arteries in small growths is another finding that should increase the safety of diagnosis.

Pancreatic veins are not normally filled following injection into the splenic artery (LUNDERQUIST 1965). Pancreatic veins draining the beta cell tumors, even when small in size, were demonstrated in seven out of nine patients of our series. Accumulation of contrast medium and demonstration of pancreatic veins were also observed in endocrine tumors of non beta cell origin and in inactive neoplasms.

Ulcerogenic growths were malignant in 60 % of the patients, benign in 30 % and in 10 % diffuse hyperplasia of the pancreas was present. According to ZBORALSKY & AUERG these tumors have never been observed by barium meal examinations before surgery or autopsy, but the gastrointestinal study is nevertheless so characteristic that it is the roentgenologist's responsibility to predict the diagnosis. The growths are usually not large enough to be observed during exploration for gastric resection, and even careful examination of the pancreas may fail to reveal a tumor 2 cm in diameter (FONTAINE et coll 1965). ZOLLINGER & MOORE (1968) recommended that a careful examination of the pancreas be performed when there are characteristic signs of an ulcerogenic tumor, and if no tumor is found that resection of the body and tail of the pancreas should be made. Preoperative angiography should therefore be carried out in these patients to depict the total vascular anatomy of the pancreas and a possible tumor. Due to the small size of the tumors in the early stages of the disease, celiac and superior mesenteric angiographies should be regarded as screening procedures and should therefore, if negative, be complemented by injection into the splenic artery. The subtraction technique may be helpful, as was the case in one of our patients.



Fig 7 Benign ulcerogenic tumor of the body of the pancreas in a 69 year old man. Combined celiac and superior mesenteric angiography was performed with negative results. Operation revealed an 8 mm large insuloma in the body of the pancreas. In retrospect identification was possible after subtraction of the angiographic studies (arrow)

SEN 1966), but as it is a somewhat more complicated procedure it should be used only in selected cases.

So far insulin producing pancreatic tumors with a diameter of less than 10 mm have not been demonstrated by angiography. Injection into the splenic artery will reveal the smaller tumors although it is doubtful whether a mass less than 5 mm in diameter could ever be demonstrated by this method. Vascular metastases in the liver from the pancreas were however revealed by the method even when they were less than 5 mm in size (Fig 8).

One important factor in pancreatic angiography is the demonstration of the entire pancreatic arterial supply. The combined injection of contrast medium into the celiac and superior mesenteric arteries is usually satisfactory in depicting the pancreatic blood supply but failed to do so in one of the present patients because of an aberrant right hepatic artery that arose directly from the aorta. A thorough knowledge of the normal and usual variations of the pancreatic vascular anatomy is necessary in order to understand small changes in the course and distribution of the vessels. Even if a tumor is detected by celiac angiography alone, the whole pancreatic supply should still be demonstrated, i.e. by superior mesenteric angiography as well. This is necessary because multiple tumors may be present which,



Fig 9 Celiac stenosis and accessory spleen in an 18-year-old man. The barium examination suggested a mass in the head of the pancreas but such examinations later as well as angiography confirmed that the wide disclosed stenosis of the celiac artery contrast medium medial to the lesion was in keeping with the mass being an accessory spleen.

one of our false positive cases in which the large amount of contrast medium was aimed for the celiac artery but was inadvertently injected into the dorsal pancreatic artery and accumulated in the body and tail of the pancreas. Failure to recognize the position of the catheter may result in a false positive interpretation.

From a differential diagnosis

as compared to those of an insuloma. Cystadenomas of the pancreas are also richly vascularized and may simulate an endocrine tumor although the cyst formation will often appear in the capillary phase.

A small accessory spleen may be closely related to the pancreatic tail (Fig 9). Even if no tumor vessels could be detected, the contrast medium remained in the spleen for a long time. The accessory spleen seems to have a more clearly demarcated border in the capillary phase. Since tumor vessels may be absent in small endocrine growths, the sharper outline of the accessory spleen seems to be the only distinguishing feature. Pharmacangiography may, however, be a method of differentiating between these two conditions.

Hepatic metastases were present in five patients (one beta cell carcinoma, one ulcerogenic carcinoma, and three carcinomas without endocrine activity), all but one having the appearance of highly vascularized nodular lesions of varying sizes. The same type of metastases have been reported previously in tumors of endocrine pancreatic origin (Boijesen 1965, 1966, Rosch & Bret 1965, Ludin et coll 1966, McGavran et coll 1966, Hernandez & Helenon 1967). The angio-



Fig 11 Malignant insulinoma in a 30 year old woman with jaundice a) and b) Celiac angiography disclosed a richly vascularized 40 mm tumor in the head of the pancreas small metastases were present in the liver The tumor was resected but the hepatic metastases could not be found c) Two month later repeat celiac angiograph revealed a local 30 mm recurrence of the tumor (arrows) and small hepatic metastases (Partial injection into the right inferior phrenic artery)

False positive angiograms of insulinoma have been reported (ROSEN & BRET, NEFESAR & POLLARD) It appears that misinterpretation may arise from an injection of contrast medium directly into the pancreatic arteries This occurred in

- Fontaine R, Kieny R et Lang G Découverte par l'angiographie sélective d'une tumeur ulcérogène du pancréas à symptomatologie atypique *Mém Acad Chir* 91 (1965), 806
- Gordon M, Rabin M, Charlevy H et coll Diarrhée aqueuse et hypokaliémie associées à une tumeur Langerhansienne non insulino-sécrétante *Presse méd* 74 (1966), 2345
- Hernandez C et Hélinon Ch Les tumeurs pancréatiques Langerhansiennes *J Radiol Electrol* 48 (1967), 339
- Hess W Über ein endokrin inaktives Carcinom der Langerhansschen Inseln *Schweiz med Wschr* 76 (1946), 802
- Lenarduzzi G, Romani S et Zaghi C La stimolazione farmacologica della funzione endocrina nella contrastografia opaca del pancreas (In Italian) *Radiol med* 54 (1968), 97.
- Ludin H, Enderlein F, Fahrlander H J and Scheidegger S Failure to diagnose Zollinger Ellison syndrome by pancreatic arteriography *Brit J Radiol* 39 (1966), 494
- Lunderquist A Angiography in carcinoma of the pancreas *Acta radiol* (1965) Suppl No 235
- McConnell F, Thompson A G and Kiss J Selective celiac and superior mesenteric angiography *Canad J Surg* 9 (1966), 15
- McGarray M H, Unger R H, Ricant L et coll A glucagon secreting alpha-cell carcinoma of the pancreas *New Engl J Med* 274 (1966), 1408
- Madien B Demonstration of pancreatic insulomas by angiography *Brit J Radiol* 39 (1966) 188
- Angiographic findings in insulomas compared with their histology Meeting of the Danish Radiological Society, Copenhagen 1968
- Meany T F and Blomcorne E Arteriographic manifestations of pancreatic neoplasm *Amer J Roentgenol* 93 (1965), 720
- Nebesar R A and Pollard J J A critical evaluation of selective celiac and superior mesenteric angiography in the diagnosis of pancreatic diseases, particularly malignant tumor Facts and 'artefacts' *Radiology* 89 (1967), 1017
- Olivier C, Helfon Ch, Esfelbaum, et coll Adénome Langerhansien hypoglycémiant. L'image artériographique *Presse méd* 74 (1966), 2313
- Olsson O Angiographic diagnosis of an islet cell tumor of the pancreas *Acta chir scand* 126 (1963), 346
- Angiographie bei Pancreastumoren *Radiologe* 5 (1965), 281
- Angiographie in drei Fällen von Insuloma pancreatis *Radiologe* 5 (1965), 286
- Pall Jr R E, Miller H H, Kohn P C et coll Pancreatic angiography with application of subselective angiography of the celiac and superior mesenteric artery to the diagnosis of carcinoma of the pancreas *New Engl J Med* 272 (1965), 283
- Rosch J Röntgenuntersuchung und Einsatz der Methoden bei Pankreaserkrankungen *Radiologe* 5 (1965), 257
- and Bret J Arteriography of the pancreas *Amer J Roentgenol* 94 (1965), 182
- Scheinin T M and Tala E Diagnosis and treatment of pancreatic islet cell adenomas *Acta chir scand* 132 (1966), 590
- Thomas R L, Robinson A E, Johnson I S et coll The demonstration of an insulin and gastrin producing pancreatic tumor by angiography and pancreatic scanning *Amer J Roentgenol* 104 (1968), 646
- Wenz W Selektive Arteriographie der Oberbauchorgane *Dtsch med Wschr* 90 (1965), 643
- van Voorthuizen A T Ervaringen met selectieve arteriografie van de arteria coeliaca en de arteria mesenterica superior (In Dutch) Thesis, Leiden 1967

graphic appearances seem to be characteristic and to be observed easier with angiography than with scintigraphy of the liver. In two of the present patients scintigraphy was normal despite multiple metastases having been present at angiography. Metastases of insulin-producing carcinomas may, however, when small, pass unobserved (MADSEN 1968), as also noted in a patient of the present series.

SUMMARY

Contrast medium was injected into the splenic or hepatic arteries in fourteen patients with various types of endocrine tumors of the pancreas. Abnormal appearances were observed in all but one patient. The differential diagnosis is discussed. The method would appear to be a safe and reliable one for diagnosing neoplasms originating from the islet cells of the pancreas.

ZUSAMMENFASSUNG

Angiographie der A. splenica oder der A. hepatica wurde in vierzehn Patienten mit verschiedenen endokrinen Tumoren des Pankreas vorgenommen. Abnorme Befunde wurden in allen mit Ausnahme von einem Patienten beobachtet. Die Differenzialdiagnose wird besprochen. Die Methode erscheint sicher und zuverlässig für die Diagnose von Inselzelltumoren.

RÉSUMÉ

Les auteurs ont injecté un moyen de contraste dans l'artère splénique ou dans les artères hépatiques de quatorze malades atteints de différents types de tumeurs endocriniennes du pancréas. Ils ont trouvé des images anormales chez tous ces malades sauf un. Ils étudient le diagnostic différentiel. Cette méthode semble sans danger et fidèle pour le diagnostic des néoplasies provenant des cellules insulaires du pancréas.

REFERENCES

- BAUM S., ROY R., FINKELSTEIN A. K. and BLAKEMORE W. S.: Clinical application of selective celiac and superior mesenteric arteriography. *Radiology* 84 (1965), 279.
- BOJSEN E.: Selective hepatic angiography in primary and secondary tumors of the liver. *Rev. int. Hépat.* 15 (1965), 385.
- Selective pancreatic angiography. *Brit. J. Radiol.* 39 (1966), 481.
- BOOKSTEIN J. J. and OBERMAN H. A.: Appraisal of selective angiography in localizing islet-cell tumors of the pancreas. *Radiology* 86 (1966), 682.
- BREIDAHL H. D., PRIESTLY J. T. and RYNGARSON E. H.: Hyperinsulinism. Surgical aspects and results. *Ann. Surg.* 142 (1955), 698.
- BLOMOCORE E., MFANEY T. F., SKILLERN P. G. and CRUIK JR. G.: Functioning pancreatic islet-cell adenoma diagnosed preoperatively by means of splanchnic arteriography. *Arch. intern. Med.* 116 (1965), 824.
- CLEMETT A. R. and PARK W. M.: Arteriographic demonstration of pancreatic tumor in the Zollinger-Ellison syndrome. *Radiology* 88 (1967), 32.

CAROTID ANGIOGRAPHY IN CLUSTER HEADACHE

by

K. EKBOM and T. GREITZ

The pathogenesis of cluster headache is not completely understood. Most authors have suggested that the pain is due to local dilatation of branches of the external carotid artery (HORTON 1956, 1961, FRIEDMAN & MIKROPOULOS 1958, WOLFF 1963) with release of a pain threshold lowering substance into the perivascular tissues. It is well recognized, however, that some patients may exhibit signs of a partial Horner's syndrome, either permanently or only transiently during the attacks. This seems to indicate that in these patients the lesion responsible for the actual pain is localized in the internal carotid artery as well.

It is a matter of interest that the headache in repeated attacks occurs strictly unilateral on the same side of the head. Only occasionally does the pain alternate from side to side. This clearly contrasts with migrainous headaches and suggests a different pathophysiologic basis for the attacks. Hitherto no definite explanation has been offered for this peculiar type of headache. The present study was undertaken on the hypothetical basis that anatomical variations in the size of the carotid artery, e.g. arteriectasis, in relation to the bony structures of the skull, particularly its foramina, might be of significance in cluster headache. All carotid angiographies performed in patients with this condition were therefore carefully examined and particular attention paid to the caliber of the internal carotid artery and its branches at different levels. The measurements were compared

Submitted for publication 28 October 1969

- VUORINEN P. and WESTLIUS U. Angiography of the celiac area (In Finnish) *Duodecim* 87 (1966) 102
- ZBORALSKE F. F. and AMBERG J. R. : Detection of the Zollinger Ellison syndrome the radiologists responsibility. *Amer J Roentgenol* 104 (1968) 529
- ZOLLINGER R. M. and MOORE F. T. : Zollinger Ellison syndrome comes of age. *J Amer med Ass* 204 (1968) 361

CAROTID ANGIOGRAPHY IN CLUSTER HEADACHE

by

L. LKBOM and T. GREITZ

The pathogenesis of cluster headache is not completely understood. Most authors have suggested that the pain is due to local dilatation of branches of the external carotid artery (HORTON 1956, 1961, FRIEDMAN & MIKROPOULOS 1958, WOLFF 1963) with release of a pain threshold lowering substance into the perivascular tissues. It is well recognized, however, that some patients may exhibit signs of a partial Horner's syndrome, either permanently or only transiently during the attacks. This seems to indicate that in these patients the lesion responsible for the actual pain is localized in the internal carotid artery as well.

It is a matter of interest that the headache in repeated attacks occurs strictly unilateral on the same side of the head. Only occasionally does the pain alternate from side to side. This clearly contrasts with migrainous headaches and suggests a different pathophysiologic basis for the attacks. Hitherto no definite explanation has been offered for this peculiar type of headache. The present study was undertaken on the hypothetical basis that anatomical variations in the size of the carotid artery, e.g. arteriectasis, in relation to the bony structures of the skull,

may influence the development of cluster headache. All carotid arteries were therefore carefully examined by angiography, including the branches of the internal carotid artery, at different levels. The measurements were compared

Submitted for publication 28 October 1969

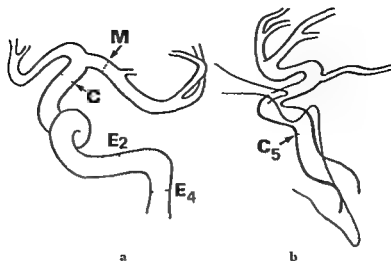


Fig. 1 Diameters of the internal carotid and middle cerebral arteries determined in a p (a) and lateral (b) roentgenograms at carotid angiography

with controls having normal findings at angiography. In addition, one patient was studied during an attack. It appears that such investigations have not previously been carried out.

Material and Methods The material consisted of 18 patients (13 men and 5 women) aged 25 to 62 years (mean 40.3 years) investigated during the period 1947–1969. Thirteen patients were personally interviewed by one of the authors, the histories in the remainder being obtained from the case records. The clinical diagnosis of cluster headache was made mainly according to the criteria given by SCHILLER (1960), HORTON (1961) and the AD HOC COMMITTEE on 'Classification of Headache' (1962). Two patients had the 'upper' and sixteen the 'lower' syndrome of cluster headache (EKBOM & KUGELBERG 1968).

Carotid angiography This was performed by percutaneous puncture of the internal or common carotid artery. Sodium- and methyl-diatrizoate (Urografin) was used as contrast medium in about two-thirds of the patients with cluster headache as well as in the controls. In the remainder, iodopyracet (Umbradil) was mostly used. In nine patients, carotid angiography was performed on the right side, in eight on the left, and in one patient bilaterally. Seven patients were investigated as a routine procedure prior to resection of the greater superficial petrosal nerve (GARDNER et al. 1947), while the remainder of the patients underwent angiography for diagnostic purposes early in the course of disease. One patient was studied during an attack of headache, which presumably was elicited by the injection of the contrast medium.

Table 1

Prediction equations for mean values of diameters in millimeters of internal carotid artery within the carotid canal (E_2 and E_4) as influenced by sex and external biparietal diameter (W expressed in centimeters) — These equations are determined from a 'normal' material of 60 males and 62 females

Measurement	Male	Female
F_2 A p. projection	$3.093 + 0.2698 W$	$2.370 + 0.2698 W$
E_2 Half axial projection	$3.610 + 0.2698 W$	$2.887 + 0.2698 W$
E_4 A p. projection	$5.101 + 0.0874 W$	$4.784 + 0.0874 W$
E_4 Half axial projection	$5.518 + 0.0974 W$	$5.205 + 0.0874 W$

The influence of sex on measurement F_2 is significant at the 0.1% level and the influence of projection is significant at the 1% level. The influence of skull width is significant at the 5% level. With regard to F_4 , the corresponding significance levels are 5%, 1% and not significant.

Angiographic measurements Measurements of the internal carotid and middle cerebral arteries were performed (Fig. 1). 'Normal' values for the extradural part of the internal carotid artery (C_5), for the intradural part (C) and for the middle cerebral artery (M) were obtained according to GABRIELSEN & GREITZ (1970). The normal material of these authors consisted of 156 strictly selected angiographies from 72 males and 84 females aged 13 to 69 years (mean 33 years). Most of the patients had a clinical diagnosis of epilepsy. (For further details, see GABRIELSEN & GREITZ.) The standard error of measurement related to a single determination was estimated to be less than 0.15 mm for these measurements. Because anatomical variations of the internal carotid artery in relation to the bony structure of the skull might possibly be of significance in the pathogenesis of cluster headache, two additional measurements were obtained (Table 1), one at the midpoint of the horizontal part of the carotid canal (E_2) and one measurement close to its external aperture (E_4). These measurements were also made in 122 of the 156 patients whose angiographies had been used as controls in the above mentioned study (GABRIELSEN & GREITZ). The excluded 34 angiographies had filling insufficient for accurate measurements due to the use of a non-venal angiographic technique.

Results

1 General angiographic findings Four of the eighteen patients had generalized ectasia of all cerebral arteries. They were all males; in addition, two females had questionable ectatic changes. In the remaining patients, the findings at carotid angiography were essentially within normal limits. Two patients with ectasia

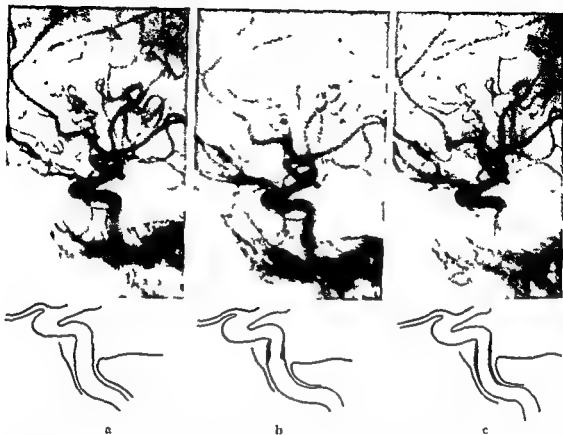


Fig 2 Appearances of the carotid siphon before and during an attack of cluster headache before the onset of pain (a) a few minutes after the beginning of the attack (b) and shortly before its termination (c) The thick contours in the explanatory sketches indicate constricted areas

had additional angiographic studies: one was examined with vertebral angiography and the other with aortocervical angiography. These examinations also revealed ectatic cerebral vessels. One female patient without arteriectasis when first examined was found by aortocervical angiography, performed 19 years later at the age of 52, to have developed generalized ectasis. She had not had any period of headaches for the previous 17 years.

2 Angiography during an attack of cluster headache One patient was examined before and during an attack.

This patient was a 42-year-old man, who was admitted to hospital with recurrent attacks of severe headache, occurring mostly during the night and lasting for 20 to 30 minutes at a time. The pain was always localized to the left eye and referred to the teeth of the upper jaw. Associated signs during the attacks were conjunctival injection, lacrimation, rhinorrhoea, sweating and a homolateral partial Horner's syndrome (miosis and ptosis).

Table 2

Mean values \pm SD for various diameters of the cerebral arteries expressed in millimeters

	Cluster headache observed values	Normal cases observed values	Normal cases adjusted values	Difference between values in cluster headache and adjusted normal values
C	4.87 \pm 0.60 (n = 17)	4.57 \pm 0.46 (n = 156)	4.78	+0.09
M	4.18 \pm 0.50 (n = 17)	3.82 \pm 0.43 (n = 156)	4.16	+0.02
C ₂	6.60 \pm 0.77 (n = 18)	5.80 \pm 0.76 (n = 156)	6.33	+0.27
E ₂	7.30 \pm 1.12 (n = 17)	7.19 \pm 1.02 (n = 122)	7.76	-0.46
E ₄	6.74 \pm 0.82 (n = 17)	6.48 \pm 0.73 (n = 122)	6.71	+0.03
C + M + C ₂	15.65 \pm 1.41 (n = 17)	14.19 \pm 1.31	15.26	+0.39

Carotid angiography was performed by puncture of the left internal carotid artery. Rapid serial angiography was used with two films a second during the arterial phase. The appearances of the carotid artery during the first series of films before the onset of headache are demonstrated in Fig. 2a. Fifteen minutes after the injection of the contrast medium (Urografin 60%) the patient developed severe headache, which was identical to his spontaneous attacks. A second injection of contrast medium was then made, and films were taken in the same projection. Localized narrowing of the extracranial part of the internal carotid artery (Fig. 2b) was observed distal to its exit from the carotid canal (corresponding to the area in which measurement C₂ was taken). The ophthalmic artery was markedly dilated. About 15 to 20 minutes later, the patient experienced slight pain in the left eye but not in the upper jaw. A third injection was then made and another film was obtained (Fig. 2c). It was observed that the narrowing had spread in a proximal direction as far as the upper part of the carotid canal.

3. Angiographic measurements. The results of the measurements of the various diameters of the cerebral arteries are given in Table 2. The observed mean values in patients with cluster headache were all greater than in the 'normal' material. The observed normal values were adjusted for those variables that had turned

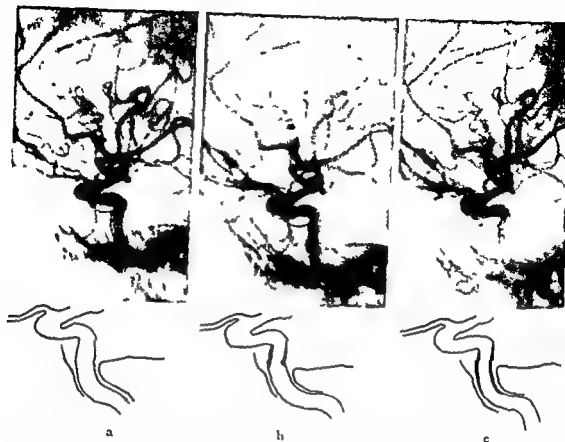


Fig 2 Appearances of the carotid siphon before and during an attack of cluster headache before the onset of pain (a) a few minutes after the beginning of the attack (b) and shortly before its termination (c) The thick contours in the explanatory sketches indicate constricted areas

had additional angiographic studies one was examined with vertebral angiography and the other with aortocervical angiography. These examinations also revealed ectatic cerebral vessels. One female patient without arteriectasis when first examined was found by aortocervical angiography, performed 19 years later at the age of 52, to have developed generalized ectasia. She had not had any period of headaches for the previous 17 years.

2 Angiography during an attack of cluster headache One patient was examined before and during an attack.

This patient was a 42-year-old man, who was admitted to hospital with recurrent attacks of severe headache, occurring mostly during the night and lasting for 20 to 30 minutes at a time. The pain was always localized to the left eye and referred to the teeth of the upper jaw. Associated signs during the attacks were conjunctival injection, lacrimation, rhinorrhoea, sweating and a homolateral partial Horner's syndrome (miosis and ptosis).

The literature records a few isolated instances of cluster headache in which the anatomy of the cerebral arteries was unusual. Thus, HORTON (1941) described a 31 year old male who was operated upon because of intractable pain. The middle meningeal artery, explored through a subtemporal craniotomy, was found to be large and tortuous and to have a particularly large posterior branch. SAFFER (1962) reported the case of a 26 year-old man with severe cluster headache, who underwent ligation of the common carotid artery. At operation, the carotid bifurcation was found to be normal but the internal carotid artery was almost a direct continuation of the common carotid artery and was increased in size. The external carotid artery, on the other hand, was much smaller than usual. Following the operation the headache disappeared but the exact length of the observation period was not given in SAFFER's paper. In six patients on the other hand, carotid angiography was stated to be normal (NIEMAN & HURWITZ).

Our results showed that some patients with cluster headache have generalized ectasia of cerebral vessels. The mean values of all measurements of arterial size were greater than in the normal material (GABRIELSEN & GREITZ) but this tendency disappeared after adjustments for the fact that most patients with cluster headache were males and (independent of sex) had fairly wide skulls. The latter observation is of particular interest as it has been suggested that patients with cluster headache have unusually broad skulls (GRAHAM 1969). This matter will be further investigated in a future work.

It is well recognized that the tone of cerebral arteries are chiefly regulated by the arterial p_{CO_2} and blood pressure (cf. LAGAR & LASSER 1965). Vasoconstriction has been observed at cerebral angiography during hypocapnia (HUBER & HANDA 1967). Admittedly, no determinations of A_pCO_2 or blood pressure were made in our patients. However, there seems to be no obvious reason to presume that any systematic differences as regards these parameters have been present between the normal material and the patients with cluster headache. It would not appear either that the results were biased by differences in the vascular activity of the different contrast media as these were used in largely the same proportions in both materials.

The narrowing of the extradural parasellar part of the internal carotid artery seen during the height of the headache attack in one of our patients could have been due to either spastic contraction or oedema of the wall of the vessel. The fact that it appeared only a few minutes after the onset of symptoms may speak slightly in favour of spastic contraction.

However it is well recognized that a certain latency period precedes the induced attack of headache (HORTON 1961, EKBOM 1968) and during this period oedema may develop. The narrowing seen within the bony canal cannot

out to be of importance in each exploration. Measurements M , C and C_5 were adjusted to correspond to patients with epilepsy, examined with rapid serial angiography and having normal findings at encephalography. Normal values for E_2 are mean values for all patients measured and therefore include those with migraine and other types of headache as well as those with epilepsy. The normal values were further adjusted with respect to the following variables: sex and skull width for C , M and C_5 ; sex, skull width and projection for E_2 and E_1 . This amounts to calculating the arterial sizes that would be met in a normal material having a composition comparable to the present material with cluster headache. In consequence, differences between values expected by this adjustment and average arterial sizes observed in the cluster headache series cannot reasonably be ascribed to these variables. After the adjustment, differences exceeding 0.15 mm were observed only for two individual measurements (C_5 and E_1) but these differences were not significant ($P > 0.05$).

Discussion

There is reason to assume clinically that cluster headache attacks are preceded by or associated with a change of the autonomic nervous control of the tone of certain cranial arteries. Presumably, a limited area of the vascular tree is involved. The attacks are characterized by signs and symptoms indicating a local increase of parasympathetic activity (GARDNER *et coll.* 1947). In this connection the presence of signs of a partial Horner's syndrome is of interest. In contradistinction to a complete Horner's syndrome, there is no anhidrosis over the face during cluster headache attacks. On the contrary, ipsilateral hyperhidrosis of the forehead is not uncommon and indicates stimulation of sympathetic nerve fibres travelling along the external carotid artery to supply the sweat glands. Observations made by KUNKLE & ANDERSON (1960) and NIEMAN & HURWITZ (1961) suggest that these minor eye signs are caused by oculosympathetic paresis rather than parasympathetic stimulation. This partial Horner's syndrome might be due to repeated dilatation and oedema of the internal carotid artery resulting in damage to the sympathetic nerves that surround the vessel.

A detailed analysis of the size of relevant segments of the internal carotid artery in relation to corresponding measurements in a control group was therefore considered to be of interest. It was felt that measurements at different levels in the carotid canal as well as of the intracranial extradural portion of the artery would be of particular significance. Normally, these portions of the carotid have an external elastic lamina, which apparently is not present in its intradural portion or in any of the other cerebral vessels (RATINOV 1964).

ZUSAMMENFASSUNG

Karotisangiographie wurde an 18 Patienten mit Horton'schem Kopfschmerzsyndrom ausgeführt, von denen vier eine ausgeprägte Erweiterung und zwei mögliche Erweiterung der Arterien hatten. Während der akuten Attacke konnte eine lokalisierte Verengung des extraduralen Abschnittes der A. carotis interna deutlich festgestellt werden, im Endstadium der Attacke erstreckte sich die Verengung bis zum oberen Abschnitt des Karotiskanal. Diese Veränderungen wurden wahrscheinlich durch Kontraktion der Arterienwand und vom Ödem hervorgerufen.

RÉSUMÉ

Les auteurs étudient chez 18 malades les résultats de l'angiographie carotidienne dans le cluster headache. Quatre de ces malades avaient une ectasie artérielle nette et deux avaient une ectasie douteuse. Au cours d'une crise il y avait un rétrécissement localisé net de la partie extra durale de la carotide interne, au stade final de la crise le rétrécissement s'était étendu jusqu'à la partie supérieure du canal carotidien. Il est possible que ces modifications soient dues à la constriction et à l'œdème de la paroi artérielle.

REFERENCES

- BICKERSTAFF E R Ophthalmoplegic migraine. *Rev Neurol* 110 (1964), 582.
- CLASSIFICATION OF HEADACHE. Report of Ad Hoc Committee. *J Amer med Ass* 179 (1962), 717.
- ERBOM K Nitroglycerin as a provocative agent in cluster headache. *Arch Neurol (Chic)* 19 (1968), 487.
- FRIE S Ophthalmoplegic migraine. *Arch Neurol (Chic)* 7 (1962), 320.
- GABRIELSEN T and GREFFZ T Normal size of the internal carotid, middle cerebral and anterior cerebral arteries. *Acta Neurol Scand* 47 (1971), 1.
- GARDNER W Ophthalmoplegic migraine. *Arch Neurol (Chic)* 7 (1962), 320.
- GRAHAM J R The physical and physiological characteristics of patients with cluster headache. 3rd (International) Symposium of the Migraine Trust, London, 24-25th April 1969.
- HORTON W T The use of histamine in the treatment of specific types of headaches. *J Amer med Ass* 116 (1941), 377.
- Histaminic cephalgia: differential diagnosis and treatment. *Mayo Clin Proc* 31 (1956), 325.
- Histaminic cephalgia (Horton's headache or syndrome). *Maryland med J* 10 (1961), 178.
- HUBER P and HANDA J Effect of contrast material, hypercapnia, hyperventilation, hypertonic glucose and papaverine on the diameter of the cerebral arteries. Angiographic determination in man. *Invest Radiol* 2 (1967), 17.

be due to spastic contraction only, as this would bring about a vacuum between the vessel wall and the cortex of the bone. Vacuum phenomena are known in connection with extension of joints and degenerated discs and are clearly seen at roentgen examination. Hence, the only possible explanation for the increase of soft tissues within or outside the wall of the vessel is an increase in fluid, i.e. oedema. The changes observed in this portion of the artery seem to develop more slowly than in the parasellar part, which is not completely surrounded by bone. The narrowing of the internal carotid artery remained or even increased after the period of maximal pain and may possibly be the initiating factor that relieved the headache. In this connection, radiologic observations made in ophthalmoplegic migraine are of interest. WALSH & O'DONERTY (1960), in two cases of ophthalmoplegic migraine, demonstrated narrowing of the internal carotid artery in the cavernous sinus. This was interpreted as evidence of an oedematous swollen vessel, these changes being precipitated by the migrainous attack. BICKERSTAFF (1964) performed carotid angiographies in ten cases of ophthalmoplegic migraine and observed in one of them, 48 hours after the onset of symptoms, a distinct constriction of the vessel in and below the region of the cavernous sinus. After complete recovery angiography was repeated and found to be normal. Similar changes, although to a lesser degree, were recorded in four other cases. This seems to indicate that oedema or constriction of the arterial wall, might have contributed to the peripheral nerve palsies in these cases.

Several carotid arteriographies have however been performed in patients during ophthalmoplegic migrainous attacks without any demonstrable abnormalities (FRIEDMAN *et coll.* 1962, PEARCE 1968).

Acknowledgements

This investigation was supported by a grant (to T.G.) from the Medical Research Council of the Swedish Life Offices. We are grateful to Prof. Lars Leksell and Dr. Torsten Bingley for permission to study the patients from the Department of Neurosurgery.

SUMMARY

The findings at carotid angiography were analyzed in 18 patients with cluster headache of whom four patients had definite and two questionable arteriectasis. Localized narrowing of the extradural part of the internal carotid artery was observed during an attack in the final stage of which the narrowing had spread to the upper part of the carotid canal. These changes are possibly due to constriction and oedema of the arterial wall.

- JAGVAR D H and LASSEN N A Regional cerebral blood flow. An international symposium. Acta neurol scand (1965) Suppl No 14
- KUNKLE E C and ANDERSON W B Dual mechanisms of eye signs of headache in cluster pattern. Trans Amer neurol Ass 85 (1960), 75
- NIEMAN F A and HURWITZ L J Ocular sympathetic palsy in periodic migrainous neuralgia. J Neurol Neurosurg Psychiatr 24 (1961), 369
- PEARCE J The ophthalmological complications of migraine. J Neurol Sci 6 (1968), 73
- RATNOV G Extradural intracranial portion of carotid artery. Arch Neurol (Chic) 10 (1964), 66
- SATTER L A Cluster headache. Case report of a variant type. Ohio med J 58 (1962), 917
- SCHILLER I Prophylactic and other treatment for histaminic cluster, or limited variant of migraine. J Amer med Ass 173 (1960), 1907
- WATSH J P and O'DOHERTY D S A possible explanation of the mechanism of ophthalmoplegic migraine. Neurology 10 (1960) 1079
- WOHLF H G Headache and other head pain. Second edition. Oxford University Press New York 1963

SIALOGRAPHY OF THE SUBLINGUAL GLAND

A modified technique enabling subtraction

by

B. LILJQVIST and U. WELANDER

Sialography is a roentgenologic method mainly applied in the examination of the parotid and submandibular glands. Roentgen examination of the sublingual gland has not been used to the same extent, probably because of the unfavourable anatomic relations of the gland with its many short excretory ducts often opening separately along the sublingual fold. GARLST (1964) maintained that it is seldom possible to achieve contrast filling of the duct system of the sublingual gland, and that on the rare occasions when this is obtained the result is usually unsatisfactory. He had however succeeded where Bartholin's duct or the ducts of Rivinus from the larger or smaller portion of the sublingual gland opened into the excretory duct of the submandibular gland. This was also pointed out by HETZAR in 1942 and recently by SCHLZ (1969), who also succeeded with selective catheterisation in 12 patients.

The sublingual gland is a salivary organ, measuring 3 cm in length and 1 cm in width and depth, situated anteriorly on the floor of the mouth in immediate relation to the mylo-hyoid muscle and the inner surface of the mandible, it produces a long ridge, the sublingual fold on the floor of the mouth. The posterior

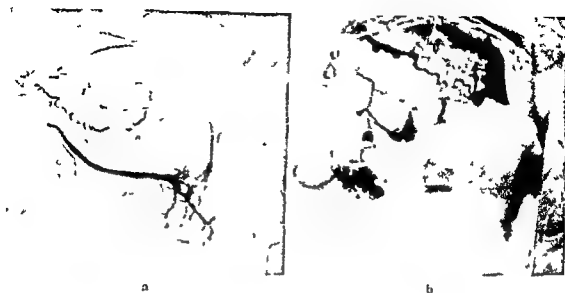


Fig. 1 a) The duct system of a sublingual gland filled via Wharton's duct b) An excretory duct of a sublingual gland filled by selective catheterisation

part of the gland is sometimes in contact with the anterior surface of the submandibular gland

The excretory ducts of the sublingual gland may vary considerably in number, as many as 48 ducts, each one opening separately on the sublingual fold, have been recorded. Usually, however, there is one large common duct, the duct of Bartholin, running from the larger part of the gland, and one or several lesser passages, the ducts of Rivinus, leading from a smaller part of the gland. Bartholin's duct is a long passage terminating either in Wharton's duct immediately behind its orifice, or in a separate opening immediately beside the orifice. The smaller excretory ducts may also open into the submandibular duct, and when this occurs their openings lie in its proximal segment.

These anatomic relations make it difficult to work out a roentgenologic method for examination of the sublingual gland. Where the gland has many separate excretory ducts, an examination can be carried out only when one or other of these can be catheterized. When one or several passages open into the submandibular duct the situation is different. On the few occasions in which the sublingual gland has filled incidentally in connection with sialography of the submandibular gland the same type of pathologic changes have been observed in this gland as in the other salivary glands. Improvement in the technique of sialography in such a way that the sublingual gland could also be investigated when the anatomic relations permit would obviously be of value.

Polythene catheters, introduced into Wharton's duct, are used nowadays for



Fig. a) A sublingual gland filled selectively via Wharton's duct. b) The duct system of a submandibular gland filled after the catheter has been passed further into the excretory duct of the gland.

sialography of the submandibular gland. The duct is narrowest at its orifice and for the rest of its length its calibre is usually greater. Without preliminary catheterisation with metal cannulae a large catheter cannot be inserted unless its tip is extended. When the sublingual gland is to be included in the sialographic examination the catheter should not be passed for any distance into Wharton's duct but should rather be placed so that the increasing calibre of the catheter occludes the orifice. If the extended tip is short the contrast medium can be injected into Wharton's duct immediately behind the orifice, this is the only way by which the excretory ducts opening into Wharton's duct from the sublingual gland can be filled.

The sublingual gland is fairly small and its position is such that it overlies the mandible in lateral roentgenograms. This is another reason why the gland is difficult to identify at sialographic examinations. The present authors have demonstrated in another connection (LILJEQVIST & WELANDER 1969) that a simple modification of the sialographic procedure enables the subtraction technique to be applied in sialography of the parotid gland. Narrow passages even if depicted in enclosing bone structures may thus be identified. The subtraction technique is therefore of great value in the study of the sublingual gland. A film changer permitting the exposure of several roentgenograms without any movement of the patient during the examination has proved valuable in this connection.

The authors have used this method in bilateral sialography of the submandibular and sublingual glands in 10 patients. The duct system of the sublingual

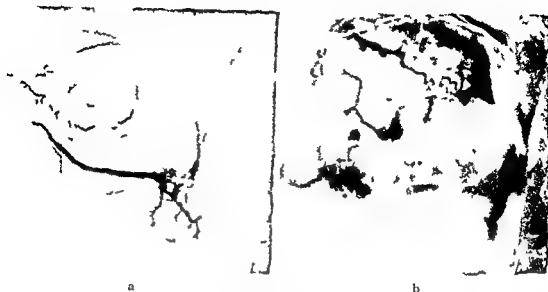


Fig. 1. a) The duct system of a sublingual gland filled via Wharton's duct. b) An excretory duct of a sublingual gland filled by selective catheterization.

part of the gland is sometimes in contact with the anterior surface of the submandibular gland.

The excretory ducts of the sublingual gland may vary considerably in number as many as 48 ducts each one opening separately on the sublingual fold have been recorded. Usually, however, there is one large common duct, the duct of Bartholin, running from the larger part of the gland and one or several lesser passages, the ducts of Rivinus, leading from a smaller part of the gland. Bartholin's duct is a long passage terminating either in Wharton's duct immediately behind its orifice, or in a separate opening immediately beside the orifice. The smaller excretory ducts may also open into the submandibular duct and when this occurs their openings lie in its proximal segment.

These anatomic relations make it difficult to work out a roentgenologic method for examination of the sublingual gland. Where the gland has many separate excretory ducts, an examination can be carried out only when one or other of these can be catheterized. When one or several passages open into the submandibular duct the situation is different. On the few occasions in which the sublingual gland has been filled incidentally in connection with sialography of the submandibular gland the same type of pathologic changes have been observed in this gland as in the other salivary glands. Improvement in the technique of sialography in such a way that the sublingual gland could also be investigated when the anatomic relations permit would obviously be of value.

Polythene catheters introduced into Wharton's duct are used nowadays for



Fig. 4 An overfilled sublingual gland after selective injection of contrast medium



Fig. 5 Bartholin's duct a long excretory duct running parallel to and of the same width as Wharton's duct

amounts are required for the examination of the duct system of the sublingual gland. Great care should be exercised during the injection so as to avoid the risk of overfilling (Fig. 4).

Bartholin's duct is a relatively long passage which, for part of its course, runs alongside Wharton's duct (Fig. 5). It is sometimes of large calibre, especially when it serves as the main excretory duct for the larger part of the sublingual gland. Parenchymal filling was obtained in all patients and this was of assistance in the assessment of the size and shape of the gland. Changes of the same type as those seen in sialectasia of the parotid and submandibular glands were evident in one of the patients (Fig. 3a).

The examinations of the sublingual gland so far performed are still too few for definite conclusions to be reached regarding the value of the method, the frequency of pathologic changes, and their relation to changes in other salivary glands. Similarly, no conclusion can yet be drawn as to how often the duct system of the sublingual gland can be demonstrated with this method.

SUMMARY

The sublingual gland and its ducts have been successfully demonstrated in a small number of patients by means of a simple modification of the sialographic procedure. The factors concerned in obtaining filling of the gland are discussed.



Fig. 3 a) Selective filling of Bartholin's duct. Areas of stlectasia in the sublingual gland b) The ducts of Rivinus and the excretory duct of the submandibular gland filled at a later stage of the examination

gland could be filled through the submandibular duct (Fig. 1a) in 5 of the patients, in one the duct system of the sublingual gland alone was outlined through selective catheterisation of its excretory duct (Fig. 1b). In one of the 6 patients an anterior and a posterior part of the sublingual gland was filled through two different excretory ducts. Thus, in 5 out of 20 examinations, the duct system of the sublingual gland was outlined through Wharton's duct and in 2 patients selective catheterisation could be performed. Furthermore, in 2 of the patients selective filling of the sublingual gland alone was achieved during the first stage of the examination (Fig. 2a). Afterwards, when the catheter was introduced a little further and more contrast medium injected, the duct system of the submandibular gland was also demonstrated (Fig. 2b). In one of these patients first Bartholin's duct and then Rivinus' ducts were demonstrated (Fig. 3, a and b).

Thus if the extended part of the catheter tip is placed immediately inside the orifice in the first stage of the examination, the duct system of the sublingual gland may usually be demonstrated. In the second stage, the catheter is pushed further into Wharton's duct in order to demonstrate the duct system of the submandibular gland, if this has not already been achieved during the first stage. Selective filling of the sublingual gland may also be obtained by passing the catheter tip into passages that open beside the main excretory duct of the submandibular gland.

The authors employ Urografin 60 % as contrast medium, only very small

TRANSCAVAL INJECTION OF THE PORTAL VEIN

A preliminary report on a new technique

by

M. HÄVERLING, C. O. OVENFORS and S. DALLGREN

Progress in the field of surgery during recent years has rendered possible operative treatment of lesions of the liver, such as primary tumours, solitary metastases and echinococcus cysts. Pre-operative localization of the intraparenchymatous lesion and of the hepatic vessels by angiography has thus increased in significance. Methods for demonstrating the portal veins are described in the literature, i.e. coeliacography (ODMAN 1958), splenoportophlebography (ABEATICI & CAMPI 1951, ARNER & FERNSTROM 1963, BERGSTRAND & FÄMAN 1957, BOLLAIN *et coll.* 1952, LEGER *et coll.* 1951) and injection of the portal vein, via mesenteric veins (ABEATICI & CAMPI 1951, MOORE & BRIDENBACH 1950) or the umbilical veins (BOLLAIN *et coll.* 1951, KESSLER & ZIMMON 1966). Selective examination of the hepatic veins with contrast medium may also be performed (NORRHAGEN 1963). As these examinations provide insufficient demonstration of the vessels and may be technically difficult to perform, the authors have attempted to devise a simple yet effective procedure for better exploration of the hepatic venous system. HÄVERLING & OVENFORS (1968) carried out translumbar puncture of the portal vein in pigs and in a few cases in man, the catheterization of the vessel in pigs

ZUSAMMENFASSUNG

Die Sublingualdrüse und ihre Gänge konnten in einer kleinen Serie von Patienten mittels einer einfachen Modifizierung der Sialographie-Technik gut dargestellt werden. Die Faktoren, die zur Füllung dieser Drüse führen, werden diskutiert.

RÉSUMÉ

La glande sublinguale et ses canaux ont été bien mis en évidence chez un petit nombre de sujets par une simple modification de la technique sialographique. Les auteurs examinent les facteurs de l'opacification de cette glande.

REFERENCES

- GARUSI G. F. The salivary glands in radiological diagnosis. *Bibl. Radiologica* Fasc. 4. S. Karger, Basel 1964.
- HETZAR W. Die Sialographie. G. Thieme Verlag, Leipzig 1942.
- LILIEQUIST B. and WELANDER U. Sialography. New application of the subtraction technique. *Acta radiol. Diagnosis* 8 (1969), 228.
- SCHULZ H. G. Das Röntgenbild der Kopfspeicheldrüsen. J. A. Barth, Leipzig 1969.

of Nembutal (Abbott) via a plastic cannula inserted in an ear vein (HARRING 1966). A red teflon catheter with only one hole at the tip was introduced via the right femoral vein into the inferior vena cava. In the first two pigs a mesenteric vein was exposed and catheterized with a polythene catheter PL 160. Contrast medium was then injected into the portal vein via this catheter at the same time as contrast medium was injected into the vena cava.

The animals were placed in the supine position for puncture of the portal vein. The transeptal puncture instrument was introduced into the teflon catheter previously placed in the vena cava. The tip of the instrument was pushed 2 to 3 mm outside the extremity of the catheter in the inferior vena cava and directed ventrally at the level of the lowest rib. Under fluoroscopic control, the instrument was directed through the anterior wall of the inferior vena cava and guided ventrally about 4 cm further, and about as many centimetres cranially. The catheter was passed over the distal part of the instrument again, the instrument was withdrawn and the catheter left in place. The catheter was then slowly pulled down during continuous aspiration until blood was seen to flow. The location of the catheter tip was checked by the injection of a small quantity of Urografin 76 %. One to 8 punctures were made during the various experiments before the catheter could be placed in a suitable position, and in two of the experiments the location of the catheter was adjusted with the aid of a guide wire temporarily introduced into the catheter and the portal vein (SELINGER PE 160). On one pig two puncture attempts were made with the animal in the lateral position. The portal vein was punctured at the third and final attempt with the animal in the supine position.

The angiographic examinations were made with the animals in lateral and supine positions with a vertical beam direction. The films were exposed in an AOT Elema film changer for cut film with 2 exposures per second for 7 seconds. The contrast medium (Urografin 60 %, 1.5 ml per kg body weight), was injected for each angiography. The injection rate was 12 ml/sec in the first 5 experiments and 14.5 ml/sec in the remainder. All pigs were in good condition after the experiments. Pig No. 2 was sacrificed on the day after the experiment. The portal vein was inspected and four pieces each about $1 \times 2 \times 3$ cm in size, were taken from different parts of the liver for microscopy.

Results

It was invariably possible to puncture and catheterize the portal vein, although several attempts were usually necessary. Thus, while one puncture resulted in an



Fig. 1 a) Simultaneous injection of contrast medium into the inferior vena cava and the portal vein after transscaval catheterization. The vena cava (arrow) is almost directly dorsal to the portal vein. b) Simultaneous contrast injection into the vena cava and portal vein. Note the proximity of the vessels in the sagittal plane.

was made by the SEIDINGER technique (1933). The films obtained demonstrate the peripheral branches of the portal vein so that the diagnosis of lesions as small as 0.5 cm in diameter is probably possible.

Translumbal puncture has certain technical disadvantages. A fairly large part of the portal vein lies anterior to the spine and may be difficult to puncture. Both the anterior and posterior walls of the inferior vena cava must be punctured. It was noted in translumbal portography (HÄVELING & ÖFVÉNORS) that the inferior vena cava is situated almost directly dorsal to the portal vein in front of the third rib, as counted from below (the number of ribs in the pig is variable), and about 2 cm in a cranial direction (Fig. 1). The drawbacks of the translumbal approach would be avoided if the portal vein could be catheterized from the inferior vena cava. A technique has been developed whereby catheterization can be performed transscavally with an instrument constructed for transeptal puncture of the left atrium (BEVEGÅRD *et coll.* 1961).

Material and Methods The experiments were performed in 11 pigs weighing between 35 and 50 kg. The animals were anesthetized by intravenous injections

inferior vena cava and the portal vein and in carrying out the punctures and catheterizations. If the puncture was unsuccessful at the first attempt, it was made about 1 cm cephalad in subsequent attempts, and at the same time the instrument was directed slightly to the right. The puncture sites in the inferior vena cava could be easily determined by reference to the spine and ribs on fluoroscopy.

On angiography of pig No. 6 in the supine position, part of the contrast coil. To avoid the catheter for pushed over a

guide wire PE 205

Postmortem examinations in this small series indicated that there are probably no major risks involved with procedure of puncturing and catheterizing the portal vein. No changes were observed in the liver at microscopy after repeated injections of Urografin 60% in association with the examinations. It was thus possible to examine the portal veins of the animals with several projections and repeated injections of contrast medium.

Acknowledgement

This investigation was supported by the James Picker Foundation on recommendation of the Committee on Radiology of the National Research Council.

SUMMARY

A new technique for direct puncture of the portal vein via the inferior vena cava, with the aid of an instrument designed for transeptal cardiac puncture is described. Satisfactory demonstration of the portal vein and its branches was obtained at subsequent angiography. No significant injuries attributable to the procedure could be established on macroscopic or microscopic examination of the liver in the experimental animals.

ZUSAMMENFASSUNG

Eine neue Technik für die direkte Punktion der Pfortader via der Vena cava inferior, mit Hilfe von einem Instrument für transeptale Herzpunktion wird beschrieben. Angiographie mittels dieser Methode ermöglicht gute Darstellung der Pfortader und ihrer Äste. Makroskopische und mikroskopische Untersuchung der Leber in Versuchstieren zeigte keine bedeutende Verletzungen, die der Methode zuzuschreiben sind.

RÉSUMÉ

Description d'une nouvelle technique de ponction directe de la veine porte par la veine cave inférieure au moyen d'un instrument conçu pour la ponction cardiaque transeptale. L'angiographie faite par cette ponction donne des images satisfaisantes de la veine porte et de ses branches. L'examen macroscopique ou microscopique du foie des animaux d'expérience n'a pas montré de lésions importantes imputables à cette technique.



Fig. 2. Phlebogram 2.5 sec (a) and 5 sec (b) after commencement of injection

immediately suitable position of the catheter in one pig, two to five attempts at puncture were necessary in 11 pigs and eight attempts in 2 pigs. Demonstration of the portal veins was obtained in all the examinations (see Fig. 2 a and b). An extravascular injection of the contrast medium occurred in pig No. 6 examined in the supine position.

No change of any kind could be established on microscopy of the livers. Postmortem inspection of the puncture zone between the inferior vena cava and the portal vein usually revealed nothing abnormal. Small red spots in the intima were observed on the anterior wall of the inferior vena cava and both the anterior and posterior walls of the portal vein in pig No. 2, these were probably caused by small intimal bleedings following the punctures.

Discussion

With the exception of pigs Nos 1 and 2, the transcaval punctures of the portal vein were performed without previous localization of the portal vein by mesenteric phlebography. In pig No. 1, the first 2 punctures were made with the animal in the lateral position. The third and fourth punctures, which were both successful, were made with the animal in the supine position. It appeared easier to guide the instrument with the animals in the supine position and consequently subsequent punctures were made in this manner. Fluoroscopy in two planes naturally would have been of value, but the prerequisites for this did not exist during the experiments. With the aid of the experience gained from previous experiments, there was no difficulty to establish the anatomic relationships of the

RETINAL AND CEREBRAL FAT EMBOLI FOLLOWING LYMPHOGRAPHY WITH OILY CONTRAST MEDIA

by

K. F. RASMUSSEN

The complications of lymphography with oily contrast media are usually mild and transitory, e.g. general malaise, nausea, headache, elevated temperature, and in some instances allergic cutaneous reactions (DOLAN 1966). At the first International Symposium on Lymphology, July 1966, in Zurich (PROGRESS IN LYMPHOLOGY) serious sequelae were reported in 198 out of 16 501 lymphographies (18 with a fatal outcome). These consisted of pulmonary infarcts (96 cases), pneumonia (27 cases), pulmonary oedema (10 cases), cerebral affections (8 cases), and other serious conditions (e.g. anuria, hyper- or hypotensive crisis, acute cardiac failure, and venous and arterial thrombosis) (57 cases).

The cerebral complications manifest themselves in various neurologic signs, such as changes in consciousness, confusion, excitement followed by stupor and possibly coma — depending upon the severity and localization of the cerebral anoxaemia (EYSON 1961).

One case of cerebral complications and retinal fat emboli has occurred in some 750 lymphographies of the present material.

Case report

Woman, aged 35, with stage IV Hodgkin's disease, who had hepatomegaly, a mediastinal mass, right pleural effusion and bilateral pulmonary infiltration, only slight enlargement of

Submitted for publication 30 July 1969

REFERENCES

- ABFATIGI S et CAMPI L. Sur les possibilités de l'angiographie hépatique — La visualisation du système portal (Recherches expérimentales) *Acta radiol* 36 (1951) 383
- ARNER O and FRANSTRÖM I. The value of spleno portography in the diagnosis of malignant metastases in the liver and in the assessment of the operability of malignant tumors in the stomach and pancreas *Acta chir scand* 129 (1965), 615
- ARONSON A F and NYLANDER G. Use of direct portography in diagnosis of liver disease *Radiology* 88 (1967) 40
- BAYLY J H. The use of the umbilical vein in the diagnosis of upper gastrointestinal bleed *Amer J Gastroenterol* 41 (1964), 235
- BROGSTRAND I and EKMAN C A. Percutaneous hemo portal venography. Technique and complications *Acta radiol* 47 (1957), 369
- BVEGÅRD S, JONSSON B and KARLÖF I. Percutaneous technique for transeptal left heart catheterization via the right femoral vein *Scand J clin Lab Invest* 13 (1961) 439
- BOULVIN R, CHIFFAUME M, GALLIS P et NACCI M. La portographie per voie splénique transpariétale *Acta chir belg* 50 (1951) 534 et 51 (1952), 192
- GONZÁLES CARBALINARS O. A preliminary report of a new technique via the umbilical vein *Clin Proc Child Hosp* 15 (1949), 120
- HÄVERLING M. Renal phlebography. An experimental study in the pig *Acta radiol* (1966) Suppl No 251
- and ÖVENFORS C O. Translumbar portography. A preliminary communication concerning a new method *Invest Radiol* 3 (1968) 376
- KLISLER R E and ZIMMON D S. Umbilical vein angiography *Radiology* 87 (1966) 841
- LEGER L, ALLOT G et ARVAY N. La phlébographie portale dans l'exploration des affections hépatospléniques *Presse méd* 59 (1951) 1230
- MOORE G E and BRIDENBAUGH R B. Portal venography *Surgery* 28 (1950) 827
- NEDESSAR R A, POLLARD J J and STONE D L. Angiographic diagnosis of malignant diseases of the liver *Radiology* 86 (1966) 284
- NORHAAGEN A. Selective angiography of the hepatic veins. Experimental investigations of basal circulatory dynamics *Acta radiol* (1963) Suppl No 221
- PARKS A G and COUCH R S. Portal venography via the hemorrhoidal veins *Lancet* 1962 I p 136
- RAPPAPORT A M. Hepatic venography *Acta radiol* 36 (1951) 165
- SELDINGER S I. Catheter replacement of the needle in percutaneous arteriography *Acta radiol* 39 (1953) 368
- ÖDMAN P. Percutaneous selective angiography of the coeliac artery *Acta radiol* (1958) Suppl No 159

RETINAL AND CEREBRAL FAT EMBOLI FOLLOWING LYMPHOGRAPHY WITH OILY CONTRAST MEDIA

by

K. E. RASMUSSEN

The complications of lymphography with oily contrast media are usually mild and transitory, e.g. general malaise, nausea, headache, elevated temperature, and in some instances allergic cutaneous reactions (DOLAN 1966). At the first International Symposium on Lymphology, July 1966, in Zurich (PROGRESS IN LYMPHOLOGY) serious sequelae were reported in 198 out of 16 501 lymphographies (18 with a fatal outcome). These consisted of pulmonary infarcts (96 cases), pneumonia (27 cases), pulmonary oedema (10 cases), cerebral affections (8 cases), and other serious conditions (e.g. anuria, hyper- or hypotensive crisis, acute cardiac failure, and venous and arterial thrombosis) (57 cases).

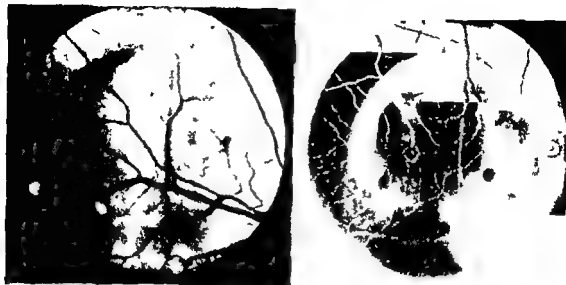
The cerebral complications manifest themselves in various neurologic signs, such as changes in consciousness, confusion, excitement followed by stupor and possibly coma — depending upon the severity and localization of the cerebral anoxaemia (EYSON 1961).

One case of cerebral complications and retinal fat emboli has occurred in some 750 lymphographies of the present material.

Case report

Woman aged 35 with stage IV Hodgkin's disease who had hepatomegaly, a mediastinal mass, right pleural effusion and bilateral pulmonary infiltration, only slight enlargement of

Submitted for publication 30 July 1969



Retinal photo (Tetrachrome X) of the right and left eyes respectively. Effusions of the oil contrast medium and a few small haemorrhages following lymphography.

the lymph nodes could be seen. The patient however felt well and had no neurologic signs. Lymphography of the retroperitoneal lymph nodes was performed. 0.8 ml patent blue violet (without any added local anesthetic) being injected into the first intermetatarsal spaces of both feet. By half an hour the lymphatic vessels on the dorsa of the feet became distinct and under local anaesthesia (lidocaine with adrenalin) a lymphatic on each side was injected with 8 ml oily contrast medium (Lipiodol ultrafluide) during 2 hours. There were no symptoms in direct connections with the lymphography but the patient gradually became drowsy and about 5 hours after the lymphography appeared to be unable to see.

Ophthalmologic examination the same afternoon revealed doubtful perception of light but normal pupillary reactions. Ophthalmoscopy indicated bilateral mild retinal oedema, several small shiny whitish yellow spots which were assumed to represent contrast medium in the end arterioles while at a few sites in or around the vessels small grey ill defined effusions and a few small round haemorrhages were evident (see figures). The disks were normal. The patient could answer only simple questions, exhibited right-left confusion and acalculia. Mild diffuse weakness of the upper limbs and a trace of reflex preponderance with a positive Babinski sign of the right leg were present. During the next three days the condition was practically unchanged; the patient remained drowsy although an ophthalmologic examination indicated that the ischaemic retinal oedema was regressing. During the subsequent week she slowly picked up and on the tenth day after the lymphography the vision was again practically normal although ophthalmoscopy still revealed droplets of the contrast medium in the vessels and ill defined greyish effusions. Ophthalmologic examination three weeks later: Vision in both eyes 0.67. Perimetry 6/2000 white + red normal. The droplets of contrast medium had now disappeared but there were still greyish effusions. Entirely normal appearances did not return until six weeks later at which time the neurologic conditions were also completely normal. The patient is discharged without symptoms.

Discussion

In the cases reported in the literature a time relation between the lymphography and the onset of the complications has existed although the latter have not always appeared in immediate connection with the examination being delayed for hours up to a few days. It may be assumed therefore that the sequelae are not always due to embolization or allergy to the contrast medium, but that in some instances the reaction is of a chemical nature and caused by fatty acids split off from the medium. This latter assumption would explain the cerebral complications, although fat emboli might also reach the brain by way of Batson's venous plexuses or through a right-left shunt in the heart (KOFER et coll 1964, *PROGRESS IN LYMPHOLOGY* 1966).

The incidence of complications appears to be related to the amount of contrast medium injected. According to DOLAN (1966), complications occurred in 13% of cases in which 18 ml were given, in 24% of those in which 18 to 20 ml were used, and in 48% when more than 20 ml contrast medium had been administered. The most common complications were fever, nausea, vomiting, and pain at the site of injection.

The fat emboli syndrome is relatively common following fractures.

FRTZ & HOGAN (1948) found the retinal capillaries to be filled with fat and there were fatty infiltrations of the surrounding stroma in patients who had died of cerebral fat emboli.

The diameter of a fat embolus may range from 6 to 40 μ with the majority from 12 to 15 μ ; accordingly, they never occur in large vessels (RACH 1968). The small petechial haemorrhages that are generally present are due to obstruction and consequent disruption of the capillaries (NEWMAN 1948).

The blindness in the present case must be assumed to have been of a cortical nature (KIMMOTT et coll 1955), with due regard to the retained pupillary reactions the fact that the ophthalmoscopic findings could not explain the visual impairment and that the patient had definite cerebral symptoms.

The Lipiodol ultrafluid contrast medium may in this case conceivably have passed to the brain not only through Batson's plexuses and the pulmonary circulation but also through a bypass in the pulmonary tumour tissue.

SUMMARY

A case of fat emboli in the retina and brain following lymphography is reported. The complications of lymphography and the phenomenon of retinal fat emboli are discussed.

ZUSAMMENFASSUNG

Nach Lymphographie ereignete sich in einem Fall eine Fettembolie des Gehirnes und der Retina. Die Komplikation der Lymphographie und das Erscheinen einer Fettembolie der Retina werden kritisch besprochen.

RÉSUMÉ

Présentation d'un cas d'embolies graisseuses dans la rétine et dans le cerveau après une lymphographie. L'auteur examine les complications de la lymphographie et le phénomène des embolies graisseuses rétinienne.

REFERENCES

- DOHAN P. A. Lymphography. Complications encountered in 522 examinations. *Radiology* 86 (1966) 876.
- EMSON H. E. Fat embolism studied in 100 patients dying after injury. *Acta chir. scand.* 122 (1961) 294.
- FRITZ M. H. and HOGAN M. J. Fat embolization involving human eye. *Amer. J. Ophthalm.* 31 (1948) 527.
- GEIHN L. E. and INGEMAN B. Rheomacrodex — a new dextran solution for rheological treatment of impaired capillary flow. *J. clin. Pathol.* 11 (1958) 28.
- KINMONTH J. B., TAYLOR G. N. and HARPER R. A. K. Lymphangiography in clinical survey and particularly in the treatment of lymphoedema. *Brit. med. J.* 1 (1955) 940.
- KOLHLE P. R., WOHL G. F. and SCHAEFFER B. Lymphangiography — a survey of its current status. *Amer. J. Roentgenol.* 91 (1964) 1261.
- MOPIL P. O. Three cases of fat embolism treated with low molecular dextran. *Svensk Läk. Tidn.* 59 (1962) 1233.
- NEWMAN P. H. The clinical diagnosis of fat embolism. *J. Bone Jt. Surg.* 30 B (1948) 290.
- PROGRESS IN LYMPHOLOGY. Edited by A. Rüttimann. Georg Thieme Verlag, Stuttgart, 1966.
- RASK J. A. Post-traumatic fat embolism located in the retina. *Acta ophthalm.* 46 (1968) 218.

FIBROMUSCULAR HYPERPLASIA IN CHILDREN

by

POLI F ANDERSEN

Since the publication by LEADBETTER & BURLAND (1938) of the first case of fibromuscular hyperplasia of the renal artery of a pelvic kidney in a 5 year old hypertensive boy, reports on this disease in children have been exceedingly rare. The disease was disregarded for more than 20 years until the report by WYLIE & WELLINGTON (1960) again suggested a causal relation between renal hypertension and fibromuscular hyperplasia. The extensive use of nephro-angiography in the last decade has revealed a number of cases, mainly in young and middle-aged Californian women, and at the same time disclosed the occurrence of the disease in extrarenal vascular areas (WYLIE, BINGLEY & PALUBINSKAS 1966). The frequency in children is still insignificant. WELLINGTON (1963) had one patient under 10 years of age, while HARRISON et coll (1967) had two children of 6 and 9 years of age among 66 histologically verified cases of fibromuscular dysplasia. MACDONALD & McMILLAN (1963), SUTTON et coll (1963) and HALFMAN et coll (1964) had no children in their case materials.

There appears therefore to be justification for reporting cases with renal and extrarenal lesions, particularly as there seem to be no reports in the literature of fibromuscular hyperplasia (or dysplasia as proposed by HILL & ANTONIUS 1965) of the vertebral arteries, like one of the present cases. This child (Case 2) appears to be the first to be reported with fibromuscular hyperplasia of the ca-

Submitted for publication on 15 April 1969

ZUSAMMENFASSUNG

Nach Lymphographie ereignete sich in einem Fall eine Fettembolie des Gehirnes und der Retina. Die Komplikation der Lymphographie und das Erscheinen einer Fettembolie der Retina werden kritisch besprochen.

RESUMÉ

Présentation d'un cas d'embolies graisseuses dans la rétine et dans le cerveau après une lymphographie. L'auteur examine les complications de la lymphographie et le phénomène des embolies graisseuses rétiniennes.

REFERENCES

- DOLAN P. A. Lymphography. Complications encountered in 522 examinations. *Radiology* 86 (1966), 876.
- EMSON H. F. Fat embolism studied in 100 patients dying after injury. *Acta chir. scand.* 122 (1961), 294.
- IRITZ M. H. and HOCAN M. J. Fat embolization involving human eye. *Amer. J. Ophthalm.* 31 (1948), 527.
- GFLIN L. E. and INGELMAN B. Rheomacrodex — a new dextran solution for rheological treatment of impaired capillary flow. *J. clin. Pathol.* 11 (1958), 28.
- KINMONTH J. B., TAYLOR G. N. and HARPER R. A. K. Lymphangiography in clinical survey and particularly in the treatment of lymphoedema. *Brit. med. J.* 1 (1955), 940.
- KOFHLER P. R., WOHLE G. T. and SCHAEFFER B. Lymphangiography — a survey of its current status. *Amer. J. Roentgenol.* 91 (1964), 1261.
- MORLL P. O. Three cases of fat embolism treated with low molecular dextran. *Svensk Läk. Tidn.* 59 (1962), 1233.
- NEWMAN P. H. The clinical diagnosis of fat embolism. *J. Bone Jt. Surg.* 30 B (1948), 290.
- PROGRESS IN LYMPHOLOGY. Edited by A. Ruttimann. Georg Thieme Verlag, Stuttgart, 1966.
- RASK J. A. Post-traumatic fat embolism located at the retina. *Acta ophthalm.* 46 (1968), 218.

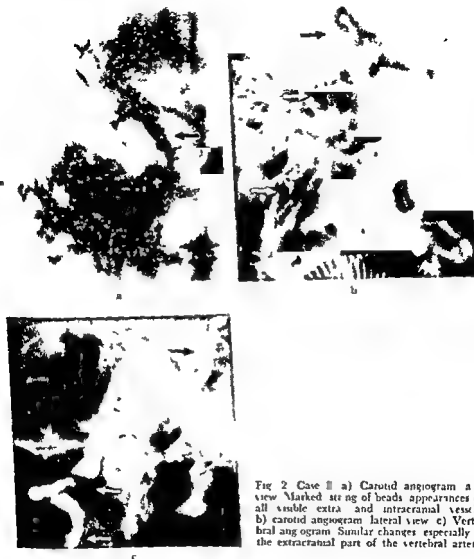


Fig 2 Case II a) Carotid angiogram a.p. view. Marked string of beads appearances of all visible extra and intracranial vessels b) carotid angiogram lateral view c) Vertebral angiogram. Similar changes especially in the extracranial part of the vertebral artery

rontothen examination of the chest was demonstrated an enlarged globular heart with a cardiothoracic ratio of 0.19.

Nephroangiography by the transfemoral route disclosed a stenosis 8 to 9 mm long with post stenotic dilatation of the right renal artery (Fig. 1a). The diameter of the stenosis was less than 3 mm. The hepatic artery and the small segmental arteries of both kidneys also varied in calibre with stenotic and dilated segments in conformity with the fibromuscular



Fig 1 Case 1 a) Arteriography. Marked narrowing with poststenotic dilatation at origin of right renal artery. b) 1 mm indentations in prepelvic part of left renal artery with marked changes in upper and middle third of kidney.

rotid arteries, although involvement of these arteries has occasionally been observed in adults, mainly middle-aged women (CONNETT & LANSCH 1965, BARKEP 1966, WILIF *et coll* 1966, EHRENFELD *et coll* 1967, and RAINER *et coll* 1968), often combined with intracranial aneurysms and subarachnoid hemorrhage (WILIF *et coll* 1966). The possible relation between fibromuscular hyperplasia or dysplasia and intracranial aneurysms is unsolved.

Case reports

Case 1 A 3 year old girl with arterial hypertension who for 2 years had had intermittent short periods of fever and several times had been admitted to a pediatric ward. Hypertrophic adenoids and large tonsils were removed at the age of 2 years following a period of fatigue. Slight transient proteinuria was recorded, the sedimentation rate was slightly increased but the AST and ASH titers and blood chemistry were normal. No changes were seen at urography. The arterial blood pressure was 100 mm Hg.

Nine months later the child was re-admitted in an extremely bad condition with cardiac insufficiency, pleurisy and pneumonia. The systolic blood pressure was 210–180 and the diastolic 160–120. The child was treated with antibiotics and digitalis with good result. Urography, urine and blood chemistry and the catecholamine excretion were normal but isotope examination of the renal function indicated decreased function of the right kidney. Ophthalmoscopy revealed a hypertonic fundus grade II with premalignant vessels at

versal vascular disease. This view is supported by the present two cases, which had multifocal lesions in a great number of parenchymatous as well as parietal vessels. Multifocal short stenoses with multiple mural aneurysms, producing the typical beaded appearances in the angiograms, were the most frequent findings, especially in the cerebral vessels and in the distal parts of the renal arteries with their segmental and subsegmental branches. Tubular and longer stenoses prevailed in the more central parts of the arteries. The differences in type and localization of the most marked lesions explain the different symptom complexes in the present cases, as well as, for instance, in those reported by FURENFELD *et coll*, STONES *et coll*, and RAINER *et coll*. The lesion which has the greatest influence on the physiologic function of an organ will be the one producing symptoms and this seems mainly to be the longer tubular stenoses. This may also explain the observations of HALFMANN *et coll* and the fact that some 30 to 40 per cent of all cases of fibromuscular hyperplasia are non hypertensive (ANDERSEN 1966).

The factor, or factors, that initiate the disease of the tunica media, whether infectious, toxic, stress, hormonal or metabolic, remain however unknown, and so far no explanation for the predominant occurrence in young female adults has been given. Although HALPERN *et coll* (1965) reported renal arteriographic signs of fibromuscular hyperplasia in three hypertensive sisters, there is no established familial or hereditary tendency nor any known association with conditions such as Marfan's disease or Erdheim's cystic medial necrosis. HARRISON *et coll* (1967) suggested that the vasa vasorum might play a significant role in the pathogenesis, and that variations in the morphologic features might be explained according to the level or extent of the vasa vasorum involvement. No apparent etiologic explanation has however been found, yet, considering the multiplicity and universal distribution of the lesions, inflammatory or collagen disease may be the more probable explanation.

The long term behaviour of the disease itself, and not only the symptoms aroused by it, is almost as unknown even in patients treated successfully by reconstructive vascular surgery or nephrectomy for a localized lesion. Very rarely, subsequent arteriographic or functional studies have been performed, and the questions as to whether early lesions will progress once hypertension has been relieved, and whether new lesions will develop, remain as unanswered as the question of the etiologic origin.

SUMMARY

Two cases of fibromuscular hyperplasia with extensive multiple lesions in young children are reported. In one of these the first to be published the fibromuscular hyperplasia included involvement of both the carotid and the vertebral arterial systems in addition to lesions of the renal, mesenteric, hepatic and lumbar arteries.

hyperplasia lesions described in adults (WYLLIE & WELLINGTON 1960, PALUBINSKAS & WYLLIE 1961, MACDONALD & McMILLAN 1963, SUTTON *et coll* 1963, and PALUBINSKAS *et coll* 1966) (Fig 1b).

Operation revealed that the right renal artery was severely stenosed corresponding with the arteriographic findings. Vascular reconstructive surgery was attempted but found impracticable, and nephrectomy was performed in the hope that this might cure the hypertension. Microscopic examination of the kidney revealed vascular lesions as described by WELLINGTON (1963) and HARRISON *et coll* (1967). Postoperatively, the systolic blood pressure fell to normal values. There was no cardiac insufficiency, the heart was not enlarged and the general condition was fairly satisfactory.

Case 2 An 11 year old boy who from the age of 2 years had been admitted several times to pediatric and cardiology wards on account of a cardiac murmur and an enlarged heart. Endocardial fibroelastosis (or myocardial disease of unknown etiologic origin), mainly localized to the left ventricle, was revealed by cardiac catheterization and cineangiography. As the boy was without major symptoms no treatment was attempted. When he was 4 years old he was thought to have psychomotor epilepsy. ECG was abnormal and he was put on anti epilepsy medication, to which he responded well. During the last 6 months prior to the actual admission the boy seemed to deteriorate mentally and had difficulty in keeping up in sports and games with children of his own age.

Two weeks prior to admission to our hospital an influenza like condition again provoked symptoms similar to those at the age of 4 years together with meningeal reactions. The boy was admitted with a diagnosis of intracranial vascular malformations with hemorrhage. No neurosomatic abnormality was found at an initial examination but the boy's extremities were slender and he had club fingers, dome shaped nails, some peripheral cyanosis and hypertension (systolic blood pressure 210–180 mm Hg).

Bilateral carotid and vertebral angiographies were performed and extensive lesions were demonstrated in all cerebral and cerebellar vessels. Innumerable small aneurysmal bulgings of the walls of the arteries created the typical string of beads sign in the carotid and vertebral arteries and their ramifications. Considerable variations in the luminal diameter were seen in the major as well as the finer vessels and the diameter of the basal ganglionic and insular ramifications of the middle cerebral artery was irregularly increased often creating an impression of angiomatic vessels. Whether an angioma *per se* was present or the appearances were due to collaterals and dysplastic, dilated arteries and arterioles could not be determined with certainty. The branches of the external carotid arteries also presented typical fibromuscular hyperplastic lesions: a biopsy specimen was taken from the superficial temporal artery which at operation felt knotty. Microscopy disclosed the characteristic appearances of fibromuscular hyperplasia (Fig 2).

Subsequent nephroangiography revealed characteristic changes of fibromuscular hyperplasia in both the renal and mesenteric arteries and even in the lumbar arteries. Interestingly enough, the arteriographic lesions seemed more marked in vessels of minor calibre.

The patient was again put on anti epileptic medication and is now well without major symptoms.

Discussion

The increasing frequency of publications of extrarenal fibromuscular hyperplasia (PALUBINSKAS & RIPLEY 1964, WYLLIE *et coll* 1966, EHRENFELD *et coll* 1967, RAINER *et coll* 1968) indicates that fibromuscular hyperplasia is a uni-

BALLOON CATHETERS AND THEIR PERCUTANEOUS INSERTION INTO THE VASCULAR SYSTEM

by

M HÄVERLING

Methods of temporary alteration of the blood flow by balloon occlusion of large blood vessels are used in angiography in order to improve the demonstration of vessels (CARLÉN *et coll* 1951, NORDENSTROM 1954, CANNON *et coll* 1956, DOTTER *et coll* 1959, NORDENSTROM 1962, STRAUBE & DOTTER 1963, NORILAGEN 1963, HÄVERLING 1966, NORDENSTROM 1966, TAKARO 1966). Most of these investigations were made during experimental research work in animals, but a report of a fairly large number of aortographies with balloon occlusion of the human aorta was published by NORDENSTROM (1966).

Balloon catheters may be inserted into the blood vessels, either by isolation of a femoral blood vessel or percutaneously according to the techniques described by NORDENSTROM (1962) and STRAUBE & DOTTER (1963). The method requiring isolation of a blood vessel has limitations in man due to the surgical procedure. This applies particularly when the catheter has to be inserted into an artery.

When a balloon catheter is introduced into a blood vessel by the percutaneous methods described, the latex balloon often produces a jagged dilatation of the puncture hole. This causes leakage of blood between the catheter and the vessel

Submitted for publication 6 June 1969

ZUSAMMENFASSUNG

Es wird über zwei Fälle von weit verbreiteten multiplen Läsionen bei fibromuskulärer Hyperplasie in jüngeren Kindern berichtet. In einem dieser Fälle konnte zum ersten Mal über das Auftreten in den Carotis- und Vertebralarterien-Systeme im Zusatz zum Auftreten in den Nieren, Mesenterial-, Leber- und Lumbal-Arterien berichtet werden.

RÉSUMÉ

Présentation de deux cas d'hyperplasie fibromusculaire avec lésions multiples étendues chez de jeunes enfants. Dans un de ces cas le premier publié, l'hyperplasie fibromusculaire touchait les deux systèmes artériels carotidien et vertébral en plus des lésions des artères rénale, mésentériques, hépatiques et lombaires.

REFERENCES

- ANDERSEN P. H. Fibromuscular hyperplasia. Paper read at the 27th Scandinavian Congress of Radiology, Oslo 1966.
- BARBER W. J. Cited by E. J. Wyllie, J. M. Binkley and A. J. Palubinskas in *Amer J Surg* 112 (1966), 149.
- CONNETT M. V. and LAUSCH J. M. Fibromuscular hyperplasia of the internal carotid artery. *Ann Surgery* 162 (1965), 59.
- EHRENFIELD W. K., STONEY R. J. and WYLIE E. J. Fibromuscular hyperplasia of the internal carotid artery. *Arch Surgery* 95 (1967), 281.
- HARRISON E. C., HUNT J. C. and BERNATZ P. E. Morphology of fibromuscular dysplasia of the renal artery in renovascular hypertension. *Amer J Med* 43 (1967), 97.
- KAUFMANN J. J., HANAUER W. and MAXWELL M. H. Upright renal arteriography in the study of renal hypertension. *JAMA* 187 (1964), 977.
- LEADBETTER W. F. and BURLAND C. F. Hypertension in unilateral renal disease. *J Urol* 39 (1938), 611.
- MACDONALD J. S. and McMILLAN J. A. Fibromuscular hyperplasia of the renal arteries. *Clin Radiol* 14 (1963), 392.
- PERLOFF D. and NEWTON T. H. Fibromuscular hyperplasia. *Amer J Roentgenol* 98 (1966), 907.
- PALUBINSKAS A. J. and RIPLEY H. R. Fibromuscular hyperplasia in extrarenal arteries. *Radiology* 82 (1964), 454.
- and WYLIE E. J. Roentgen diagnosis of fibromuscular hyperplasia of the renal artery. *Radiology* 76 (1961), 631.
- RAINER W. G., CRAMER G. C., NEWBY J. P. and CLARKE J. P. Fibromuscular hyperplasia of the carotid artery causing positional cerebral ischemia. *Ann Surg* 167 (1968), 441.
- SUTTON D., BRUNTON F. J., FOOT F. C. and GUTHRIE J. Fibromuscular fibrous and non-atheromatous renal artery stenosis and hypertension. *Clin Radiol* 14 (1963), 381.
- WELLINGTON J. S. Fibromuscular hyperplasia of renal arteries in hypertension. *Amer J Pathol* 43 (1963), 955.
- WYLIE E. J. and WELLINGTON J. S. Hypertension caused by fibromuscular hyperplasia of the renal artery. *Amer J Surg* 100 (1960), 183.
- BINKLEY F. M. and PALUBINSKAS A. J. Extrarenal fibromuscular hyperplasia. *Amer J Surg* 112 (1966), 149.



Fig 2 Catheter types A and C respectively. Balloon unexpanded (a) and (c) and expanded (b) and (d)

wall of the teflon tube to permit expansion of the balloon by injection of physiologic saline via the tube (Fig 1, A and B). At its distal end, the teflon tube is blocked with a small screw. The distal end of the latex balloon protrudes about 1 cm beyond the tip of the teflon tube. This construction of the tip of the balloon catheter makes it easier to catheterize tortuous blood vessels. An ordinary Luer-Lock one way tap may be attached to the proximal end of a catheter type A. BEVERIDGE et coll (1961) described an adapter that makes it possible to utilize two catheters simultaneously, one inside the other, during pressure recordings in the vascular system. This adapter may be used for a balloon catheter type A, if a steel wire is placed in the lumen of the catheter in order to strengthen it during balloon occlusion of the aorta. In this way, the balloon can be expanded without being pushed down by the blood stream through the vessel (HAVERLING 1966).

A balloon catheter of type II is made in the following way. The balloon holding part of the teflon tube is cut proximal to the balloon and connected to a screw (Fig 1, B-g). This screw has two different diameters and is equipped with a tapped central hole. To the proximal part of the screw are attached two plastic tubes, one inside the other, as illustrated in Fig 1, B. The inner tube, of polythene,



Fig 3 Special device for double lumen balloon catheters of types II and C

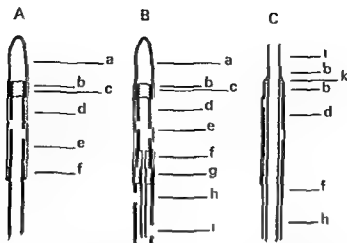


Fig 1 Distal parts of balloon catheters types A, B and C. a = tip of latex balloon, b = distal fixation of balloon to catheter, c = screw, d = latex balloon, e = balloon holding radiopaque tube, f = proximal fixation of balloon to catheter, g = metal screw with tapped channel, h = outer plastic tube, i = inner plastic tube, k = silver ring.

wall and it is therefore necessary to compress the vessel above the site of the puncture throughout the examination. It would appear that an insertion technique that eliminated this disadvantage would facilitate the use of temporary balloon occlusion of blood vessels in angiography.

Catheters. The balloon catheters described in this report were manufactured to meet the following requirements: (1) the site of the balloon, when the catheter is placed inside the vessel, should be judged during fluoroscopy with the balloon free from contrast medium, (2) the balloon catheter should be inserted into the blood vessel with the least possible trauma and (3) no compression of the blood vessel above the site of insertion should be necessary during the examination as long as the catheter is inside the vessel.

Three types of balloon catheters were made: A for simple occlusion (Fig 1, A), B for occlusion and injection of contrast medium or pressure recording proximal to the balloon (Fig 1, B), and C for occlusion and injection of contrast medium or pressure recording distal to the balloon (Fig 1, C).

The balloon catheters of types A and B are of similar design. The latex balloon is mounted on a radiopaque teflon tube, in order to diminish the diameter of the balloon it is stretched over the tube (Fig 2a). The balloon is attached at both ends to the tube with glue (Kontakt Lim, Crisco, Stockholm) and the fusions are strengthened by a fine nylon thread wrapped around the fixation sites, this thread is held fast with a small amount of glue. Two small holes are bored through the

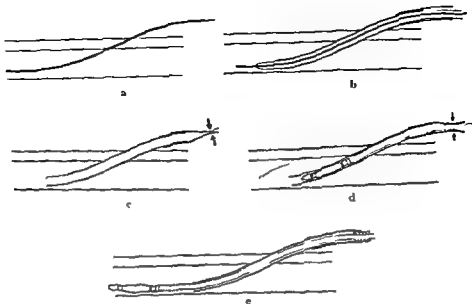


Fig 5 The different stages in the

insertion of a balloon catheter slipped through insertion tube e) Rubber plug pressed into rubber tubing or the latter clamped with forceps to unite it to the catheter

receptor The proximal end of a catheter of type C is fitted with a device similar to that used for catheters of type B (Fig 3, C)

Balloon catheter insertion technique All three types of the balloon catheters described are inserted into the vascular system in the same way A femoral artery or vein is punctured and the SELDINGER technique followed as far as the insertion of the catheter (Fig 5a) Instead of the catheter, a special insertion device is slipped over the guide wire This device consists of two teflon tubes, one inside the other The inner tube, called the dilatation tube, has a thick wall and an acute tip, the outer diameter is slightly larger than that of the balloon catheter The outer tube, called the insertion tube, has a thin but stiff wall A short piece of rubber tubing is attached to the proximal end of the insertion tube (Fig 6). The dilatation and the insertion tubes are introduced into the blood vessel together by slipping them over the guide wire (Fig 5b) and the dilatation tube and the guide wire are then withdrawn (Fig 5c) To avoid undue bleeding when this is done, the rubber tubing is pressed by the fingers (LINDGREN 1953) The balloon

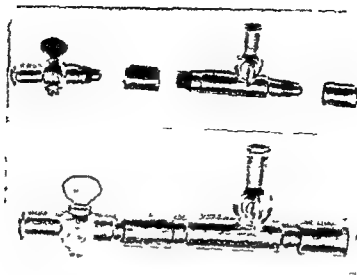


Fig 4 Special device for double lumen balloon catheters
Unassembled (upper) and assembled (lower) (without
catheters)

is screwed into the tapped central hole of the short metal screw which is used to connect the balloon holding the teflon tube to the proximal part of the catheter. The outer tube with four or more side-holes bored distally is attached to the screw. At its proximal end this type of catheter is adapted to a special device (Fig 3), made of four metal parts screwed together as illustrated in Fig 4. This device makes it possible to control both lumina of the balloon catheter simultaneously and contrast medium can be injected into the vessel proximal to the balloon occlusion through the space between the two tubes. It is also possible to use this lumen to transmit the vascular pressure proximal to the balloon occlusion to a pressure receptor. The lumen of the inner tube is used to expand the latex balloon.

A catheter type C is made of two plastic tubes, one inside the other, the inner tube protruding beyond the tip of the outer one (Fig 1, C). The distal part of the latex balloon is attached both to the distal part of the outer tube and to the inner tube, the lumen between the inner and the outer tubes is thus occluded at the tip of the catheter. The proximal part of the latex balloon is attached to the outer tube, through the wall of which two small holes are bored. A communication between the latex balloon and the space between the two tubes is thus formed and the balloon can be expanded by injection of physiologic saline into the outer tube. Contrast medium can be injected into the blood vessel distal to the balloon occlusion through the inner tube, or the vascular pressure distal to the balloon occlusion can be transmitted through this catheter lumen to a pressure



FIG. 7 Example of use of balloon catheter type II Hepatic vein phlebogram Temporary balloon occlusion of inferior vena cava in right atrium Injection of 100 ml Urografin 60% (145
 " a III the level of
 sec with patient
 or part of liver

into the vascular system. The percutaneous methods described earlier have made it possible to introduce balloon catheters into the human aorta without isolation of a femoral artery. However, when the catheter is introduced into the vessel, the latex balloon may be stretched downwards on the catheter, forming a cuff of uncontrolled diameter, when this is pushed through the wall of the blood vessel it tends to make the puncture hole jagged. Bleeding around the catheter may occur during the examination and must be controlled by compression of the vessel above the site of the puncture. The new method described makes it possible to avoid these disadvantages. By utilizing dilatation and insertion tubes, atraumatic widening of the puncture hole in the blood vessel wall is ensured by the acute tip and a smooth surface. Balloon catheters with two lumina reduce the number of punctures necessary. The technique described may also be utilized to insert other catheters without an end hole.

Balloon catheter type C can be utilized for selective occlusion of an artery,



Fig. 6 Dilatation and insertion tubes assembled (upper) and unassembled (lower)

catheter is then inserted (Fig. 5d). The rubber tubing is clamped with forceps in order to tighten it on to the catheter, or a rubber plug may be used for the same purpose (Fig. 5e). The catheter is easily rotated, pushed up or pulled down when the forceps are released. During the examination the insertion tube may be attached and fixed to the skin in the groin with plaster.

Example of the use of balloon catheters. An example of the use of a catheter type B is illustrated in Fig. 7, which shows a hepatic phlebogram obtained by injection of contrast medium below a balloon on occlusion of the inferior vena cava. The latex balloon was expanded inside the right atrium with 30 ml Urografin 30%, the catheter then being pulled down against the inferior vena cava. One or two seconds later 100 ml Urografin 60% were injected via the space between the two tubes at a rate of 14.5 ml/sec. The injection of contrast medium into the inferior vena cava was performed at the level of the hepatic veins. No other technical procedures were utilized. Two exposures per second for ten seconds were obtained, the patient was fully conscious and in supine position throughout the examination. The balloon was emptied quickly after the last exposure.

Discussion and Conclusions

The catheters described are made in such a way that it is possible to judge the site of the balloon mounted at the tip of the catheter during fluoroscopy without filling it with contrast medium.

Catheterization following isolation of blood vessels is still utilized in angiography, although satisfactory percutaneous catheter insertion methods have been described (LINDGREN 1953, SELDINGER 1953, GIDLUND 1956), in radiology of today percutaneous insertion of catheters should be the one of choice (GREITZ & LINDGREN 1961). This is also the case when balloon catheters are to be inserted.

- Balloon catheters for percutaneous insertion into the vascular system *Acta radiol* 57 (1962), 411
- Percutaneous balloon occlusion of the aorta *Acta radiol* Diagnosis 4 (1966), 365
- NORHAGEN A Selective angiography of the hepatic veins *Acta radiol* (1963) Suppl No 221
- SELDINGER H I Catheter replacement of the needle in percutaneous aortography *Acta radiol* 39 (1953), 368
- STRAUBE K. and DOTTER CH Single lumen balloon catheter for percutaneous insertion *Amer J Roentgenol* 90 (1963), 650
- TAKARO T Experimental renal phlebography A comparison with renal arteriography *Surgery* 60 (1966), 619

such as the renal artery (HAVERLING 1969). This suggests future use of balloon catheters for controlled selective arterial occlusion, i.e. during ischaemic treatment of malignant tumours.

The balloon catheters described are 'home-made' but it is hoped that they will become available commercially.

SUMMARY

New types of balloon catheters and a percutaneous insertion technique for the occlusion of vessels in angiography are described. Selective occlusion of an artery for the ischaemic treatment of malignant tumours is mentioned as an outcome of the method.

ZUSAMMENFASSUNG

Neue Typen von aufblasbaren Kathetern und eine perkutane Einföhrungstechnik zur Okklusion von Gefassen wahrend Angiographie werden beschrieben. Die Methode ermoglicht selektive Okklusion einer Arterie fur die ischamische Behandlung maligner Tumoren.

RÉSUMÉ

L'auteur decrit un nouveau type de sonde a ballonnet et une nouvelle technique d'introduction percutanee pour l'occlusion des vaisseaux au cours de l'angiographie. L'occlusion selective d'une artere pour le traitement ischémique des tumeurs malignes est signalee comme une application de cette methode.

REFERENCES

- BEVEGÅRD S, JONSSON B and KARLOF I. Percutaneous technique for transseptal left heart catheterization via the right femoral vein. *Scand J clin Lab Invest* 13 (1961) 439.
- CANNON J A, CLIFFORD C A, DIESH G and BAKER W F. Accurate diagnostic coronary arteriography in the dog. *S Forum* 6 (1956) 197.
- CARLENS E, HANSSON H E and NORDENSTROM B E W. Temporary unilateral occlusion of the pulmonary artery. *J thorac Surg* 22 (1951) 527.
- DOTTER C T, FRISCHE L H, HOSKINSON W S et coll. Coronary artery during induced cardiac arrest and aortic occlusion. *Arch intern Med* 104 (1959).
- GIDLUND Å. Development of apparatus and methods for roentgen studies in haemodynamics. *Acta radiol* (1956) Suppl No 130.
- GREITZ T and LINDGREN E. Angiography. In *Cerebral angiography* Volume 1 p 41. Little, Brown and Company, Boston 1961.
- HAVERLING M. Renal phlebography. An experimental study in the pig. *Acta radiol* (1966) Suppl No 251.
- Unilateral nephrophlebography. A preliminary report. *Invest Radiol* 4 (1969) 100.
- LINDGREN E. Technique of abdominal aortography. *Acta radiol* 39 (1953), 205.
- NORDENSTROM B. Temporary occlusion of the pulmonary artery. A method of roentgen examination of the pulmonary vessels. *Acta radiol* (1954) Suppl No 108.



Fig 1 Left selective renal angiography one week after kidney puncture. Small aneurysm in upper pole with rapid contrast filling of a vein.



Fig 2 Left selective renal angiography one week after kidney puncture. Aneurysm in lower pole and good contrast filling of the renal vein.

rabbits, the weights of the animals varied from 2.0 to 3.0 kg and the ages from 10 to 12 months. Percutaneous puncture of one of the kidneys was made under intravenous pentobarbitone (Mebumalnatium, ACO, Sweden). The needle had an outer diameter of 0.4 mm, which for the rabbit's kidney is comparable with the diameter of the needle used in human renal biopsies. Only one puncture was usually made although two or three regions of the kidney were sometimes selected. Selective catheterization of the renal artery from the femoral artery (ADAMS *et coll.* 1965) was made with a radiopaque polythene catheter (OPP 60, Portex, England), outer diameter 1.15 mm, inner diameter 0.75 mm. The catheterization was aided by magnification fluoroscopy (LJELUND & OLIN 1970), the contrast medium used being metrizoate sodium (Isopaque 350, Nyco, Norway), which was injected at a suitable and constant rate with an infusion machine (CLEMENTZ & OLIN 1963). The angiograms were made on industrial film, Structurix D4 (Agfa Gevaert) at a focus-film distance of 40 cm, mAs 20, kV 90 and 0.04 sec. The film, beneath which is a thin sheet of lead, was placed in close contact with the animal. Angiographies were usually performed one or two weeks after the puncture, followed in some animals by a second angiography four weeks after the puncture.

ARTERIOVENOUS FISTULAE SECONDARY TO RENAL BIOPSY

An experimental study in the rabbit

by

L. EKELUND

Arteriovenous fistulae of the kidney may occur secondary to needle biopsy (BOIJSEN & KOHLER 1962, FERNSTROM & LINDBLOM 1962, BLAKE et coll 1963, BENNETT & WIENER 1965, RILEY 1965, NILSSON & ROSS 1967). Even open renal biopsy may produce a renal aneurysm with fistula (FAUST 1968). The frequency is supposed to be low, which is surprising since the vascular richness of the kidney, with the consequent possibility of injury to an artery and a vein in close relationship, ought to favour fistula formation. BENNETT & WIENER, however, reported 9 arteriovenous fistulae and 2 arterial aneurysms following 58 renal biopsies. An attempt to evaluate how often an arteriovenous fistula develops secondary to needle biopsy of the kidney thus appeared justified.

Material and Methods The kidney on one side was punctured and selective renal angiography was performed at different periods after the puncture in 36

This study was supported by a grant (No B69 23A 605 03) from the Swedish Medical Research Council. Submitted for publication 17 July 1969

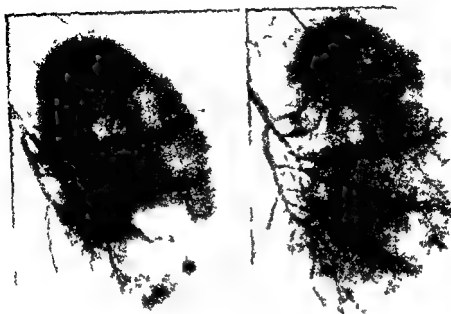


Fig 5 Left selective renal angiography one week after kidney puncture. Fistula formation between middle and upper pole

Fig 6 Same case as in fig 5 Four weeks after puncture. Closure of fistula

connection with repeat kidney puncture produced general intrarenal artery spasm and extravasation of contrast material

Four cases with proved fistulae had a second angiography four weeks after the puncture. In two of these rabbits the arteriovenous fistula had closed completely, in one it had diminished considerably, and in the fourth case it was of roughly the same size as at one week after puncture (Figs 5 and 6)

All the animals were in good condition during the experiment. No cases of macroscopic haematuria were observed although these were not especially sought.

Discussion

Reports in the literature of renal arteriovenous fistulae following renal biopsy are few. The first was reported in 1962. The largest material was presented by BENNETT & WISNER and consisted of 11 intrarenal arteriovenous fistulae and 2



Fig 3 Left selective renal angiography one week after kidney puncture Arteriovenous fistula with good contrast filling of the renal vein This rabbit was pregnant



Fig 4 Right selective renal angiography one week after kidney puncture Arteriovenous fistula in middle part of the kidney with contrast filling of the renal vein as well as the inferior vena cava Insufficient filling of glomeruli distal to the shunt

Results

Fistulae secondary to the puncture developed in 16 (44%) of the 36 cases, the size of the shunt varying. The fistula sometimes originated from a small intrarenal artery aneurysm (Fig 1) while in others it had a width of up to 2.3 mm, good contrast filling of the renal vein as well as the inferior caval vein was obtained in the latter instance (Figs 2, 3, 4). The fistulae always appeared in the medulla of the kidney and never in the cortex. Infarction peripherally to the shunt never occurred but insufficient filling of glomeruli was often evident. Insufficient filling of the arteries of other parts of the kidney was noted due to the shunting in cases with large fistulae.

Spasm of the renal artery occurred at angiography in 3 cases of arteriovenous shunt. The lumen of the renal artery varied between 1.5 and 2.0 mm in the arteriovenous shunt cases as compared with a variation of from 1.6 to 1.8 mm in the remaining material. The normal lumen of the renal artery in the rabbit is 1.7 to 1.8 mm (IDIBORN 1956), there is thus a slight widening of the renal artery in most of the cases of arteriovenous fistulae.

In a case not included in the material renal angiography, performed in direct



Fig 5 Left selective renal angiography one week after kidney puncture. Fistula formation between middle and upper pole

Fig 6 Same case as in fig 5 Four weeks after puncture. Closure of fistula

connection with repeat kidney puncture, produced general intrarenal artery spasm and extravasation of contrast material

Four cases with proved fistulae had a second angiography four weeks after the puncture. In two of these rabbits the arteriovenous fistula had closed completely, in one it had diminished considerably, and in the fourth case it was of roughly the same size as at one week after puncture (Figs 5 and 6)

All the animals were in good condition during the experiment. No cases of macroscopic haematuria were observed although these were not especially sought

Discussion

Reports in the literature of renal arteriovenous fistulae following renal biopsy are few. The first was reported in 1962. The largest material was presented by BENNETT & WIENER and consisted of 9 intrarenal arteriovenous fistulae and 2

renal aneurysms out of 58 renal biopsies. The reason so few cases have been reported is that angiographic examinations are rare in relation to the performance of renal biopsy and that cases in which biopsy has been performed are seldom followed up with renal angiography. Angiography is sometimes performed in an unsatisfactory manner — there is reason to believe that a small fistula may be overlooked if only aortography and not a truly selective examination is performed. Another reason may be a tendency of the fistulae to spontaneous healing. BENNETT & WIENER described the disappearance of the fistula in 3 cases. The fistula in the present material healed in 2 out of 4 cases, checked by angiography four weeks after puncture. (Further investigation is in progress to evaluate the frequency of spontaneous healing of fistulae.)

BLAKE *et coll.* presented 2 cases in which renal angiography was performed because of a bruit over the kidney with the fistula. In 60 other cases in which no bruits were heard, angiography was not performed, and these cases were considered free from fistula formation. Some of the fistulae in this experimental material are certainly too small or too large to give an audible bruit, and there is reason to believe that this sign is not sufficient for establishing the diagnosis.

The number of arteriovenous fistulae in this experimental work is strikingly large. It might be that this may have been due to the lumen of the needle used the outer diameter of which was 0.4 mm. The needle for human percutaneous renal biopsies has an outer diameter usually ranging from 1.5 to 2.0 mm. The rabbit's kidney has a length of from 3.0 to 3.5 cm and the human kidney a length of from 11.0 to 11.8 cm (HOFFMANN). The diameter of the needles are thus comparable in relation to the length of the kidney. Furthermore, the diameter of the renal artery in the rabbit is 1.7 to 1.8 mm, as compared with 4.6 to 9.7 mm in man (EDSMAN 1957).

Arteriovenous fistulae appear in blunt trauma as well as after perforating trauma, MUTH & OLIN (1968) reported 4 arteriovenous fistulae in 16 such cases.

There seems to be a predisposing factor in the development of human renal arteriovenous fistulae following renal biopsy, namely hypertensive disease. The hypertension may act through its haemodynamic effects or by the nephrosclerosis which it causes, in this experimental material no hypertension was provoked. Other factors that may be of importance are age and sex (hormonal influence). The animals in this experiment were young and the sex ratio was almost 50:50. One female rabbit in which a fairly large fistula developed was found to be pregnant.

Finally it should be stated that congenital arteriovenous fistulae may occur in the kidney although apparently rarely (LOVE *et coll.* 1965).

The investigation points to the fact that arteriovenous fistulae following renal biopsy are more common than usually believed and that for their proper recogni-

tion renal angiography should follow renal biopsy more often. Biopsy should however precede angiography in cases in which both renal biopsy and angiography are planned in the examination.

As mentioned above, investigation is in progress to evaluate the frequency of spontaneous fistula healing. Investigations concerning fistula formation in animals with experimental hypertension are also planned.

SUMMARY

An experimental study in the rabbit of the development of renal arteriovenous fistulae following kidney puncture is presented. Selective renal angiography was performed in 36 rabbits in which kidney puncture had been performed previously. Arteriovenous fistulae were demonstrated in 16 cases (44 per cent).

ZUSAMMENFASSUNG

An Kaninchen wurde die Entwicklung von arteriovenösen Fisteln nach Punktur der Nieren experimentell studiert. An 36 Kaninchen wurde selektive renale Angiographie nach vorheriger Punktur der Niere vorgenommen. In 16 Fällen (44 Prozent) konnten arteriovenöse Fisteln festgestellt werden.

RÉSUMÉ

Présentation d'une étude expérimentale sur le lapin concernant l'apparition de fistules artério-veineuses après ponction rénale. I. auteur a fait une angiographie rénale sélective sur 36 lapins qui avaient subi auparavant une ponction rénale. Il a mis en évidence des fistules artério-veineuses rénales dans 16 cas (44 pour cent).

REFERENCES

- ADAMS D F, OLIN T and REDMAN H C. Catheterization of arteries in the rabbit. *Radiology* 84 (1965) 531.
- BENNETT A and WIENER S. Intrarenal arteriovenous fistula and aneurysm — a complication of percutaneous renal biopsy. *Amer J Roentgenol* 95 (1965), 372.
- BLAKE S, HEFFERNAN S and MCCANN P. Renal arteriovenous fistula after percutaneous renal biopsy. *Brit Med J* 1 (1963) 1458.
- BOJSEN E and KOHLER R. Renal arteriovenous fistulae. *Acta radiol* 57 (1962) 433.
- CLEMENTZ B and OLIN T. Apparatus for controlled infusion of saline in angiography and contrast medium in lymphography. *Acta radiol* 55 (1961), 109.
- EDSMAN G. Angioneurography and suprarenal angiography. *Acta radiol* (1957) suppl No 166.
- EKLUND I and OLIN T. Catheterization of arteries in rats. *Invest Radiol* 5 (1970), 69.
- FALST H. Diagnose und Verlauf intrarenaler arteriovenöser Fisteln. *Fortschr Röntgenstr* 109 (1968) 749.

- FERNSTROM I and LINDBLOM K : Selective renal biopsy using roentgen television control J Urol 88 (1962), 709
- HOFFMANN C F F : Lehrbuch der Anatomie des Menschen E. Besold, Erlangen 1877
- IDBOHRN H : Renal angiography in experimental hydronephrosis Acta radiol (1956) Suppl No 136
- LOVE L, MONCADA R and LISCHER A : Renal arteriovenous fistulae Amer J Roentgenol 95 (1965), 364
- MUTH U och OLIN T : Subcapsulärt njurhematom studerat med angiografi och njurfunktionsprov - en experimentell studie på hund (In Swedish) Paper presented at Nordisk förening för medicinsk radiologi, Copenhagen 1968
- NILSSON C G and ROSS R J : Bilateral renal arteriovenous fistulas and decreased blood pressure following renal biopsies J Urol 97 (1967), 176
- RILEY J : Renal arteriovenous fistula - a complication of percutaneous renal biopsy J Urol 93 (1965), 333

ROENTGENOLOGIC DIAGNOSIS OF POLYCYSTIC KIDNEY AND MEDULLARY SPONGE KIDNEY

by

B I IVEMARK, C LAGERGREN and N LINDVALL

GRUBER (1927) compared the general appearances of polycystic kidneys to a sponge although today the term medullary sponge kidney is used for a specific cystic renal condition with characteristic roentgen and histologic appearances (EKSTROM et coll 1959, CACCHI 1960). Difficulties in the roentgen differential diagnosis seem to occur only in cases of polycystic renal disease of less common appearance. The purpose of this paper is to discuss the histologic and roentgen features of these two conditions.

The study was based on the roentgen and histologic examination of 8 cases of polycystic kidney and 120 cases of medullary sponge kidney. The microscopy studies were based upon biopsies and resections as well as upon autopsy cases. The age ranges at the time of examination were 1 to 50 years for polycystic kidney and 17 to 50 years for medullary sponge kidney.

Results

Polycystic kidney, described by POTTER as type 3 (OSATHANONDH & POTTER 1964), is considered to be due to multiple abnormalities of development and

This investigation was supported by grants from Svenska Läkforskningsbolaget namnd för medicinsk forskning. Submitted for publication 27 May 1969.

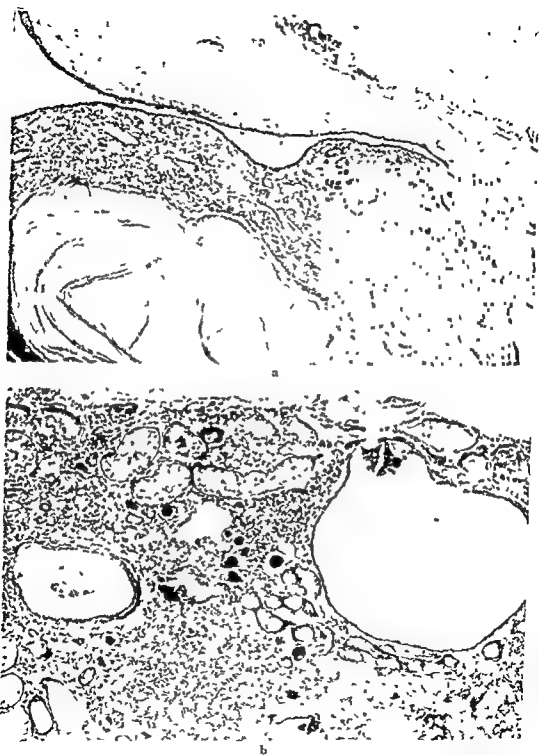


Fig 1 Polycystic kidney (POTTER type 3) a) Compression of calyceal recess by large medullary cysts b) Cortical part with one glomerular cyst (right) and one tubular cyst. Increased interstitial fibrous tissue and some normal proximal tubules present. Haematoxylin-eosin $\times 75$.

cystic changes may involve any part of the nephron (Figs 1 to 6) The lesion is usually but not always bilateral Such kidneys are generally larger than normal but increase in size with advancing age from progressive growth of the cysts. The degree of enlargement depends upon the age of the patient, the number of renal tubules involved, and the amount of fluid in the cysts, the cysts are ordinarily present throughout the renal parenchyma. The microscopy appearances vary in relation to the degree of abnormality. Normal glomeruli, normal convoluted tubules and collecting tubules are mixed with cystic dilatation of glomeruli and all parts of the collecting ducts and nephrons. This irregular intermixture is characteristic of the condition. There is also increase in the amount of interstitial connective tissue. *Primitive ducts, ductules or cartilage characteristic of polycystic renal dysplasia are not seen* (ERICSSON & ILEVIK 1958).

Cases of polycystic kidney type 3 run a variable clinical course, depending upon the extent of renal involvement. Progressive renal failure, arterial hypertension and diffuse renal pain have constituted indications for urography. One of the present cases was discovered during routine examination for trauma. A few cases, apparently with early manifestations of polycystic disease (in childhood and early adolescence) have facial features resembling those of POTTER's syndrome (hyper teleorism, low set ears and hypognathia). In none of the present cases was a family history of renal disease recorded.

Roentgenography in adults usually discloses enlarged kidneys. The urographic appearances early in the disease are normal but contrast density decreases with progressive renal insufficiency. The calyces, the necks of the calyces and the pelvis may be deformed by cysts, the calyces are often club-shaped and lack papillary impressions. Some of the pyramids contain cavities that primarily fill with contrast medium during urography. These cavities are usually few and irregular, occasionally resemble dilated collecting tubules and may contain calculi. Free concretions are sometimes present. In addition larger cysts occur similar to those found in the common adult polycystic kidney. The combination of all these forms of cysts facilitates the diagnosis. The ureters and bladder present no changes. Nephroangiography will demonstrate cysts of varying size throughout the parenchyma as in the adult polycystic kidney.

Medullary sponge kidney (EKSTROM *et al.* 1959). This appears to be a congenital malformation (Figs 7-8). The kidney may be normal in size, enlarged or atrophic largely dependent on the extent and stage of the accompanying pyelonephritis. The most striking pathologic feature is the presence of multiple small cystic cavities confined to the pyramids and consisting of both cysts and dilated collecting tubules (Fig. 7) some of the cysts may communicate with the tubules or with one another. These medullary cysts may contain calculi, usually



Fig 2 Bilateral polycystic kidneys (POTTER type 3) a) Urography at the age of 9 years. Both kidneys contain numerous irregular contrast filled cavities some of them located in the cortex. Slight deformation of some calyces b) Another case. Both kidneys contain irregular contrast filled cysts in the pyramids and larger cysts in the cortex. Haematuria was the presenting symptom

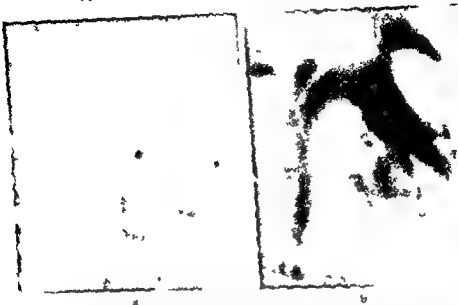


Fig 9 Bilateral polycystic kidneys (POTT'S type 3) Renal colic for several years. a) Several calculi in the enlarged kidney b) Urography. Typical irregular contrast filled medullary cavity in the lower pole. Deformation of calyces and necks of calyces caused by large cysts

of mixed calcium phosphate. Cortical cysts are not a part of the condition, but the cortex may be narrow and fibrotic owing to concomitant pyelonephritis. The loops of Henle are not hyperplastic and do not have basement membrane thickening — unlike in the nephronophthisic kidney. Large cysts compressing calyceal recesses do not occur in the medullary sponge kidney.

Medullary sponge kidney often produces renal colic and gross haematuria and sometimes pyelonephritis.

The radiologic appearances are highly characteristic with the presence of cavities of varying size and extent in the pyramids, the cavities are filled primarily with contrast medium during urography and are regularly shaped, whether oval or rounded. The cysts vary in number from a few to many and often contain calculi, their number likewise varying from a few to several hundred. If the changes are present throughout the entire medulla, the kidney may be enlarged. No changes are evident in the films in mild cases. The nephroangiographic appearances are normal.

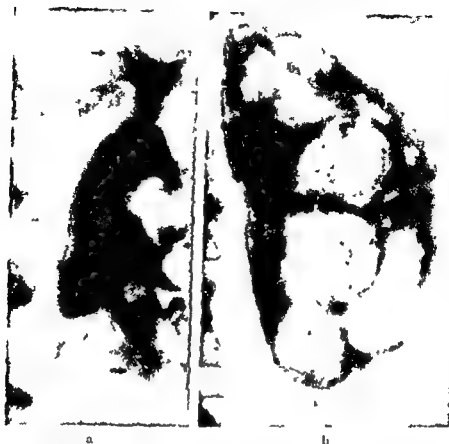


Fig 4 Unilateral polycystic kidney (POTTER type 3) Haematuria after trauma of left kidney region a) Urography Enlarged kidney with irregular contrast filled medullary cavities (arrows) Deformation of calyces and necks of calyces by large cysts b) Late nephroangiographic phase Multiple filling defects in the cortex indicating cysts

Conclusion

The histologic appearances of polycystic kidneys in the present material correspond to the description by OSATHANONDH & POTTER (1964) as 'type 3 due to multiple abnormalities of development', these authors stated (p. 512) that the type 3 polycystic kidney is the variety generally designated as polycystic kidney of the adult.

However, the present histologic, roentgenologic and clinical findings in the polycystic kidneys fail to support this view. Common so-called adult (familial) polycystic renal disease presents different histologic and radiologic appearances, without structural evidence of malformation of the renal parenchyma, without contrast-filled cavities at urography but with the presence of parenchymal calcifi-



Fig 5 Bilateral polycystic kidneys (POTTER type 3) Urinary tract infection. Urography. Enlarged kidney with small irregular contrast filled medullary cavities in some pyramids (arrows). Calyces deformed by larger cysts.



Fig 6 Bilateral polycystic kidneys (POTTER type 3) Renal insufficiency and hypertension. Pyelography. Kidney normal in size. The contrast filled medullary cavities predominate.

cations both radiologically and histologically (JENNAR & LINDBLOM 1958). Furthermore, there was no family history in the present cases nor in those of OSATHANONDI & POTTER. This is in sharp contrast to the common adult polycystic kidney. The writers therefore consider the Potter type 3 polycystic kidney as a mixture of the common adult familial polycystic kidney and an apparently non-familial separate entity. The discrepancy between the Potter classification and the clinico-radiologic appearances of polycystic kidneys has also been stressed by EBEL & OLBRING (1969). The present nine cases of polycystic kidneys tally well with those of the true non-familial Potter type 3 kidney and the series contains no common adult polycystic kidney cases.

The authors have considered four renal lesions with medullary cysts (Table). They are separate entities although they may resemble each other. However,



Fig. 4 Unilateral polycystic kidney (PORTER type 3) Haematuria after trauma of left kidney region a) Urography Enlarged kidney with regular contrast filled medullary cavities (arrows) Deformation of calyces and necks of calyces by large cysts b) Late nephroangiographic phase Multiple filling defects in the cortex indicating cysts

Conclusion

The histologic appearances of polycystic kidneys in the present material correspond to the description by OATHANONDI & PORTER (1964) as 'type 3 due to multiple abnormalities of development', these authors stated (p. 512) that the type 3 polycystic kidney is the variety generally designated as polycystic kidney of the adult.

However, the present histologic, roentgenologic and clinical findings in the polycystic kidneys fail to support this view. Common so-called adult (familial) polycystic renal disease presents different histologic and radiologic appearances, without structural evidence of malformation of the renal parenchyma, without contrast-filled cavities at urography but with the presence of parenchymal calcifi-



Fig 7 Medullary sponge kidney Ectatic and cystic collecting and papillary ducts No calculi present in this part of the kidney Haematoxylin eosin $\times 12$

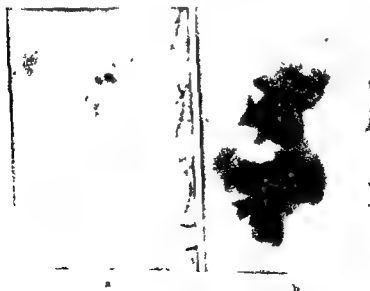


Fig 8 Unilateral medullary sponge kidney a) Group of rounded small calculi in the enlarged upper pole b) Urography Typical cavities in the enlarged papillae of the upper pole, calculi lie in some of the cavities

Table
Differential diagnosis of four renal medullary cystic lesions

	POTTER, type 3	'Common adult polycystic kidney'	Medullary sponge kidney	Nephronophthisis
Age	Infants, adults	Adults	Adults	Children adolescents
Cavities (urography)	Few, irregular	Not present	Numerous and regular	Not present
Nephroangiography	Numerous defects	Numerous defects	Normal	Atrophy, no defects
Histology	Small and large cysts of cortex and medulla increased connective tissue, sometimes calculi	Large cortical cysts sometimes with blood and calcifications, no increase in connective tissue	Cystic and ectatic collecting and papillary ducts no cortical cysts calculi in some cysts	Medullary and juxtacortical cysts tortuous loops of Henle with basement membrane thickening atrophy
Clinical features	Variable, renal pain progressive renal failure occasionally 'Potter facies'	No Potter face, renal colic, haematuria, intracranial aneurysms, progressive renal failure, hypertension	Renal colic gross haematuria pyelonephritis	Polydipsia polyuria final azotaemia no proteinuria haematuria or hypertension

these conditions are merely examples of a medullary cystic change that may occur in other states, e.g. trisomy 13—15 (GUSTAVSSON *et coll.* 1962) and nephronophthisis which is even called 'medullary cystic disease' (BROBERGER *et coll.* 1960; IVEMARK *et coll.* 1960; STRAUSS & SOMMERS 1967).

Medullary sponge kidney is easy to differentiate radiologically from tuberculosis, renal papillary necrosis and various forms of nephrocalcinosis (CACCINI 1960; LESTROM *et coll.* 1967). It may, however, be difficult to distinguish between medullary sponge kidney and polycystic kidney type 3, but certain radiologic details differ. For example, the shape and number of the cavities are of importance. They are numerous and regular in outline in the medullary sponge kidney, while they are usually few and irregular in polycystic kidney in which the small medullary cysts are accompanied by cortical cysts. The calyces and the papillae in medullary sponge kidney are normal or enlarged. The calyces of the polycystic kidney are often club shaped and lack normal papillary impressions.

REFERENCES

- BROBERGER O WINBERG J and ZETTERSTROM R Juvenile nephronophthisis *Acta paediat* 49 (1960) 470
- CACCHI R Il rene a spugna O malattia cistica delle piramidi renali (In Italian) Cappelli Bologna 1960
- DISEASE OF THE KIDNEY Edited by M B Strauss and L G Welt Little, Brown & Co, Boston 1963
- EBEL K D und OLBRING H Zur Röntgendiagnostik der polyzystischen Nierendegeneration im Kindesalter *Fortschr Röntgenstr* 110 (1969) 28
- ENSTROM T ENCFELDT B, LAGERGREN G and LINDVALL N Medullary sponge kidney Almquist & Wiksell Stockholm 1959
- — — Medullary sponge kidney *In Proc 3rd Int Congr Nephrol* Washington 1966 Vol III pp 54—64 Karger Basel/New York 1967
- ERICSSON O and IVEMARK B I Renal dysplasia and pyelonephritis in infants and children Part I *Arch Path* 66 (1958) 255
- — Renal dysplasia and pyelonephritis in infants and children Part II Primitive ductules and abnormal glomeruli *Arch Path* 66 (1958) 264
- GRUBER G B See (Die) Morphologie der Missbildungen des Menschen und der Tiere
- GUSTAVSSON K H IVEMARK B I ZETTERQVIST P and BOOK J A Post mortem diagnosis of a new double-trisomy associated with cardiovascular and other anomalies *Acta paediat* (Uppsala) 51 (1962), 686
- IVEMARK B I and LINDBLOM K Arterial ruptures in the adult polycystic kidney *Acta chir scand* 115 (1958) 100
- LILJEQVIST A and BARRY A Juvenile nephronophthisis Part II A histologic and microangiographic study *Acta paediat* (Uppsala) 49 (1960) 480
- (Die) MORPHOLOGIE DER MISSBILDUNGEN DES MENSCHEN UND DER TIERE Herausgegeben von G B Gruber Gustav Fischer Jena 1927
- NEVOY N J and FORSBERG L Polycystic renal disease presenting as medullary sponge kidney *J Urol* 100 (1968) 407
- OSATHANONDH V and POTTER E L Pathogenesis of polycystic kidneys Historical survey *Arch Path* 77 (1964) 459
- REILLY B J and VEHHAUSER E B D Renal tubular ectasia in cystic disease of kidneys and liver *Amer J Roentgenol* 84 (1960) 546
- STRAUSS M B and SOMMERS S C Medullary cystic disease and familial juvenile nephronophthisis Clinical and pathological identity *New Engl J Med* 277 (1967), 863
- and WELT L G See Disease of the kidney

EBFI et coll. described various polycystic renal changes in infants and children and their radiologic illustrations revealed several cases with the same appearances as in the present cases of polycystic kidney. However, they did not group these together but separated the infantile from the adolescent cases. It is also of some interest that as early as 1960 REILLY & NEUMHAUSER described cases of renal tubular ectasia in cystic disease, some of which had the same roentgen appearances as the present polycystic kidney cases.

The nephroangiographic differences between medullary sponge kidney and polycystic kidney type 3 are still more obvious. The former presents normal appearances while in polycystic kidney type 3 there are numerous defects of varying size in the cortex as in the common adult polycystic kidney, caused by the cortical cysts. Despite the similarity in nephroangiographic appearances in these two latter lesions, urographic differences are apparent. The common adult polycystic kidney contains no contrast-filled cavities outside the calyces and the calcifications are parenchymal, while in polycystic kidney type 3 concretions are present within the cavities.

It has recently been suggested on the basis of the findings in one case (NEMO & FORSBERG 1968) that polycystic change may occur in both the cortex and medulla when radiologic evidence of medullary sponge kidney is associated with enlarged kidneys. This was not confirmed in the enlarged kidneys of the present series of 120 cases of medullary sponge kidney.

The group of medullary cystic renal changes also includes nephronophthisis. The location and type of cysts in this condition make it theoretically possible to demonstrate them at urography, this could, however, not be confirmed in our studies.

SUMMARY

The radiologic and histologic differential diagnoses in two renal medullary cystic conditions — *polycystic kidney (Potter type 3)* and *medullary sponge kidney* — are described.

ZUSAMMENFASSUNG

Die radiologische und histologische Differenzialdiagnose in zwei medullären Zystenerkrankungen: polyzystische Niere (Potter Typus 3) und medulläre Schwammniere wird beschrieben.

RÉSUMÉ

Description du diagnostic différentiel radiologique et histologique de deux affections kystiques de la médullaire rénale: le rein polycystique (Potter type 3) et le rein en éponge.

EBEL et coll. described various polycystic renal changes in infants and children and their radiologic illustrations revealed several cases with the same appearances as in the present cases of polycystic kidney. However, they did not group these together but separated the infantile from the adolescent cases. It is also of some interest that as early as 1960 REILLY & NEUBAUER described cases of renal tubular ectasia in cystic disease, some of which had the same roentgen appearances as the present polycystic kidney cases.

The nephroangiographic differences between medullary sponge kidney and polycystic kidney type 3 are still more obvious. The former presents normal appearances while in polycystic kidney type 3 there are numerous defects of varying size in the cortex as in the common adult polycystic kidney, caused by the cortical cysts. Despite the similarity in nephroangiographic appearances in these two latter lesions, urographic differences are apparent. The common adult polycystic kidney contains no contrast-filled cavities outside the calyces and the calcifications are parenchymal, while in polycystic kidney type 3 concretions are present within the cavities.

It has recently been suggested on the basis of the findings in one case (NEVOY & FORSBERG 1968) that polycystic change may occur in both the cortex and medulla when radiologic evidence of medullary sponge kidney is associated with enlarged kidneys. This was not confirmed in the enlarged kidneys of the present series of 120 cases of medullary sponge kidney.

The group of medullary cystic renal changes also includes nephronophthisis. The location and type of cysts in this condition make it theoretically possible to demonstrate them at urography, this could, however, not be confirmed in our studies.

SUMMARY

The radiologic and histologic differential diagnoses in two renal medullary cystic conditions — polycystic kidney (Potter type 3) and medullary sponge kidney — are described.

ZUSAMMENFASSUNG

Die radiologische und histologische Differentialdiagnose in zwei medullären Zystenerkrankungen: polyzystische Niere (Potter Typus 3) und medulläre Schwammniere wird beschrieben.

RÉSUMÉ

Description du diagnostic différentiel radiologique et histologique de deux affections kystiques de la médullaire rénale: le rein polykystique (Potter type 3) et le rein en éponge.

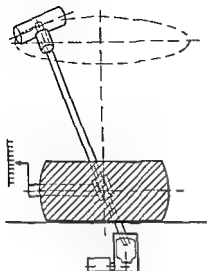


Fig 1 Principles in determining the height of the layer. The image intensifier takes the position of the cassette during fluoroscopy.

Mention should be made of the Pohl patent (1937) according to which the tomoscopic image is determined by the height of the layer corresponding to the height of the rotating mirror. The cathode beam changes the height of the layer correspondingly. These and similar systems are characterized by the fact that all but the image shadows in the pivot plane are blurred just as in a tomographic film.

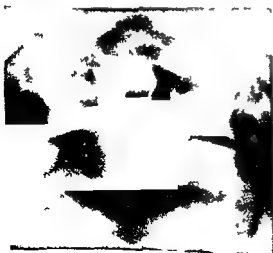


Fig 2 Dens epistropheus tomographed after centering and standstill on the monitor.

IMMEDIATE CENTERING AND TOMOGRAPHIC CUT LOCALIZATION BY MEANS OF ROENTGEN TELEVISION

by

J FRIMANN-DAAHL and H B KJELL

Positioning and ascertaining the correct pivot plane for tomographic sectioning is often a difficult as well as a time-consuming procedure. Several methods that reduce the number of trial exposures necessary for arriving at the desired section have been described in the past. Estimation of the correct level by applying anatomic knowledge is common. For example, a tomogram through the human hip joint will usually be located approximately 8 cm above the table top with the patient supine. Multisection tomography can also be used for estimation of the correct level, several cuts being taken through the region to be examined. However, the former method gives only a coarse approximation, and the latter produces considerable unsharpness due to the use of intensifying screens of varying speeds.

Trigonometric methods for ascertaining the desired layer have been tried. Exposures in two extreme tube positions are taken, and the level sought is derived from the distance the object has wandered on the screen. The Siemens Universal Planigraph utilizes this method. Various tomoscopic devices have been suggested and described, but to our knowledge none of these has been used in practice.

Submitted for publication 15 July 1969



Fig 4 Tomogram of fractured L1 in a heavy subject



Fig 5 Single tomogram of gallstone centered and arrested on the television screen

rotation per 2 seconds) with an angle of cut of 30° . The correct depth of sectioning is then found by moving the fixed pivot plane up or down until the movement of the examined object on the monitor ceases, when this occurs it must correspond to the pivot plane, as explained above. After a little experience, the observer may perform the procedure with only 5 to 10 seconds of fluoroscopy. The image intensifier is then replaced by a cassette, the object being centered and at the correct level.

Experience with the method has been promising and it has proved satisfactory for many diagnostic purposes. Its application is easiest and most striking when immovable objects such as bony structures are examined. The dens epistropheus, which is difficult to display in conventional films, could be clearly demonstrated in a tomogram, well centered and in the correct plane (Fig 2). Similar results may be obtained in the examination of the hip, the desired cut is particularly easy to find in nailed hips (Fig 3). In obese patients certain projections, for example a lateral view of the spine, may present some difficulty. The centering and selection of the correct cut is however usually possible (Fig 4).

Problems may arise in the examination of structures that move with respiration for it may be difficult to decide whether the movements are physiologic or due to the tomographic projection. These may be overcome if the patient is cooperative



Fig. 3 Tomogram of nailed hip (pseudarthrosis)

A new method utilizing a specially designed rotational tomograph has been tried by the authors. The unit is distinguished by the fact that any complicated system of rotating mirrors or the like has been avoided. The method makes use of television monitored fluoroscopy for direct visual location of the tomographic pivot plane and in its present stage of development has yielded satisfactory results.

During adjustment of the depth of the desired pivot plane, an image intensifier mounted under the bucky diaphragm is substituted for the cassette. The image intensifier thus follows the rotation of the diaphragm, synchronous with the movement of the roentgen tube, exactly as the cassette would have done. As a result of this arrangement of tube and intensifier, the object shadows that are not in the pivot plane move on the television monitor at varying speeds. The movement and rate of travel of each image detail will be dependent upon the distance of the object from the fulcrum and only the image of an object detail located in the pivot plane will remain stationary on the television screen. The image details that are 'frozen' at any given time are easily discernible.

In the examination of a patient the structure is located on the monitor for the examination, as usual. The tomograph is then set in motion (approximately) one

L'ARTERIOGRAPHIE APRÈS CATHETERISME PERCUTANÉ PAR VOIE ARTÉRIELLE AXILLAIRE

par

J F HUGLET et H NAVARRO

NEWTON en 1963 et ROY en 1965 sont les premiers à pouvoir faire état d'une série importante de cathétérismes axillaires pour explorer le cœur gauche et le système artériel. Séduits par cette voie d'abord nous l'avons utilisée fréquemment. Nous voudrions apporter notre contribution au développement de cette méthode. Elle ne nous paraît pas en effet avoir été utilisée suffisamment pour les radiographies vasculaires. Connaissant bien maintenant ses inconvénients et ses grands avantages nous répéterons sur cette rive de l'Atlantique ce que dit ROY à Montréal et nous apporterons notre expérience.

Nous envisagerons successivement la technique du cathétérisme axillaire, les applications, les résultats et la critique de la méthode.

Techniques, matériel, et mise en place de la sonde

Préparation du malade. Il ne nous paraît pas bon que le patient soit strictement à jeun, nous préférons qu'il prenne une boisson, quelle qu'elle soit, pourvu qu'elle soit abondante avant de se présenter à l'hôpital.

En effet nous pensons avec DUGUESNEL que la déshydratation consécutive à

Soumis à la Rédaction le 9 janvier 1969

and able to hold his breath for the necessary period of time. A gallstone can easily be centered and a cut taken through its equator (Fig. 5). Most difficult, if not impossible, is the examination of structures such as the biliary ducts, which are only faintly depicted on the screen; conventional methods with preliminary films for orientation are then probably better. The limiting factor in the use of the method in the examination of small objects is the contrast and resolution of the picture. With improvements in television, observation of detail that is only poorly demonstrated today may be greatly facilitated.

SUMMARY

A new method for selecting the depth of tomographic section by direct visual monitoring is described. The tube and the image intensifier move synchronously during fluoroscopy, and the movement of the object is followed on the television screen until it remains stationary. The correct depth for the tomogram is thus obtained.

ZUSAMMENFASSUNG

Eine neue Methode zur Bestimmung der Tiefenwahl für Tomographieschnitte mittels Bildverstärkerdurchleuchtung wird angegeben. Röhre und Bildverstärker bewegen sich synchronisiert während der Durchleuchtung und die Bewegung des Zielobjektes wird solange auf dem Schirm verfolgt bis es zum Stillstand kommt. Mit diesem Vorgehen erhält man die richtige Schnitttiefe.

RÉSUMÉ

Description d'une nouvelle méthode pour choisir la profondeur d'une coupe tomographique directement par radioscopie télévisée. Le tube et l'intensificateur d'image se déplacent de façon synchrone pendant la radioscopie et on suit le mouvement de l'objet sur l'écran de télévision jusqu'à ce qu'il reste stationnaire. On obtient ainsi la profondeur correcte pour la coupe tomographique.

REFERENCES

- FINKENZELLER J., GAJEWSKI H. und DENIS A.: Geräte für die Einbeziehung der Schichtuntersuchung in den allgemeinen röntgendiagnostischen Betrieb. *Radiologe* 9 (1968), 288.
 POPPE H., LAUMERS P. und LOSTOTER I.: *Technik der Röntgendiagnostik*. Georg Thieme Verlag, Stuttgart 1966.
 STIEVE F. E.: Bevorzugte Darstellung einzelner Körperschichten. In: *Encyclopedia of medical radiology*. Part III, p. 774. Springer Verlag, Berlin 1967.



Fig. 2. Rapport de l'artère axillaire et du plexus brachial. Les deux racines du médian se rejoignent (1) et le cubital (3) se dirige vers l'arrière et le cône.

jacent. Il faut être possible d'être au-delà des artères circonflexe et scapulaire inférieure qui peuvent sinon être ponctionnées inutilement. On pense aussi qu'elles peuvent aider en cas de thrombose à la revascularisation d'aval (Fig. 1).

Le point de ponction après palpation minutieuse est repéré. L'anesthésie locale doit être abondante : 20 ml de novocaïne 1%. Il faut qu'elle soit profonde. Elle peut entraîner un engourdissement temporaire de la main.

La ponction artérielle est faite avec le trocart après repérage des battements artériels : repérage au doigt puis à la pointe du trocart qui transmet le pouls. Il faut éviter les ponctions névralgiques qui risquent de blesser l'artère et les branches du plexus brachial (une bonne localisation préalable est donc essentielle).

Lorsque le sang jaillit sylvie et avec un jet de plusieurs dizaines de centimètres, le guide est mis en place sous contrôle télévisé, on le pousse jusqu'à la crosse aortique si possible et on enlève le trocart. Il faut bien comprimer la zone de ponction à ce moment-là pour éviter que l'artère ne se remplisse de sang. La sonde une fois mise en place, il n'y a plus de saignement possible. La sonde est alors enfilée sur le guide : on peut, sans que cela soit obligé, faire une moucheture au bistouri sur la peau.

Avant de franchir la peau et d'introduire la sonde dans l'artère, on s'assure de la liberté de la tête du guide afin qu'il ne perce pas une tunique sur laquelle il bute. Sous contrôle scopique, on fait alors cheminer la sonde et le guide de concert. Quand la sonde est en place, il faut retirer le guide et bien s'incer la sonde pour la laisser toujours remplie de serum et non de sang. Ce serum sera discrètement hépariné : quelques gouttes dans 250 ml de serum.

Les aléas possibles. Les deux racines du médian se rejoignent au niveau même de la zone ponctionnée et le médian couvre l'artère. Le cubital est lui aussi très proche. Il est donc fréquent que le sujet accuse des douleurs en éclairs dans

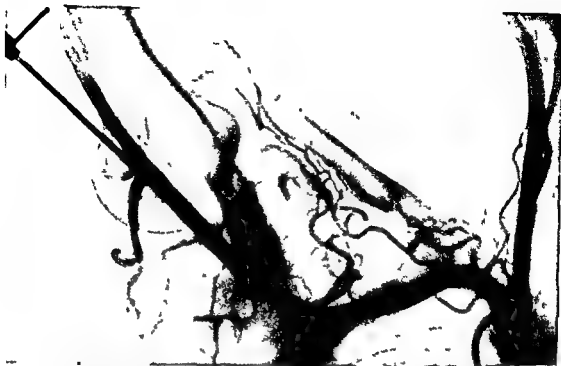


Fig 1 Radiographie de la position du trocart avant l'introduction du guide. Le point de ponction de l'artère axillaire se fait sur le plan dur de la tête humérale si possible en amont des artères circonflexe et scapulaire inférieure qui peuvent être une voie de revascularisation éventuelle

un jeûne prolongé (parfois plus de 12 heures quand le patient est vu au milieu de la matinée) amène une hémo-concentration, facteur favorisant les thromboses. Aucune prémédication n'est faite à part exception. Nous expliquons en détail au patient les manœuvres pratiquées, et attendons de lui qu'il nous fasse part de ses réactions. Quand nous sommes amenés à calmer le patient, nous nous adressons au Dolosal ou au Vallium par voie intra-veineuse ou par la sonde du cathétérisme.

Le patient en décubitus présente l'aisselle en mettant sa main sous la tête, aisselle rasée et désinfectée.

Matériel. L'examen ne peut être fait sans amplificateur et télévision. Le trocart que nous employons est du type Seldinger de diamètre variable (SELDINGER 1953, ÖDMAN 1956). Les sondes sont de plusieurs types suivant l'examen, nous employons souvent les Cordis Ducor bleues No 8, préformées et serties. La plus grande attention doit être portée au guide qui doit être adapté à la sonde en calibre et longueur et de bonne qualité.

Mis en place de la sonde. La ponction se fait dans le sommet de l'aisselle sous l'aube pectoral à la hauteur de la tête humérale qui fait un plan dur sous-



Fig 2 Rapport de l'artère axillaire et du plexus brachial. Les deux racines du médian se rejoignent (1) et le cubital (3) se dirige entre artères et veine

jaçant. Il faut si possible être au delà des artères circonflexe et scapulaire inférieure qui peuvent sinon être ponctionnées inutilement on pense aussi qu'elles peuvent aider en cas de thrombose à la revascularisation d'aval (Fig 1)

Le point de ponction après palpation minutieuse est repéré. L'anesthésie locale doit être abondante. 20 ml de novocaïne 1 % il faut qu'elle soit profonde. Elle peut entraîner un engourdissement temporaire de la main.

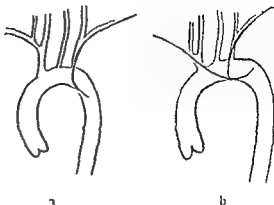
La ponction artérielle est faite avec le trocart après repérage des battements artériels repérage au doigt puis à la pointe du trocart qui transmet le pouls. Il faut éviter les ponctions itératives qui risquent de blesser l'artère et les branches du plexus brachial (une bonne localisation préalable est donc essentielle).

Lorsque le sang jaillit rythmiquement et avec un jet de plusieurs dizaines de centimètres le guide est mis en place sous contrôle télévisé on le pousse jusqu'à la crosse aortique si possible et on enlève le trocart. Il faut bien comprimer la zone de ponction à ce moment là pour éviter que l'aisselle ne se remplisse de sang. La sonde une fois mise en place il n'y a plus de saignement possible. La sonde est alors enfilée sur le guide on peut sans que cela soit obligé faire une mouche-ture au bistouri sur la peau.

Avant de franchir la peau et d'introduire la sonde dans l'artère on s'assure de la liberté de la tête du guide afin qu'il ne perfore pas une tunique sur laquelle il bute. Sous contrôle scopique on fait alors cheminer la sonde et le guide de concert. Quand la sonde est en place il faut retirer le guide et bien rincer la sonde pour la laisser toujours remplie de sérum et non de sang. Ce sérum sera discrètement hépariné quelques gouttes dans 250 ml de sérum.

Les alevas possibles Les deux racines du médian se rejoignent au niveau même de la zone ponctionnée et le médian couvre l'artère. Le cubital est lui aussi très proche. Il est donc fréquent que le sujet accuse des douleurs en éclairs dans

Fig. 3 Si la crocette est normale (a) le guide descend tout droit dans l'orte de s'engageant. Si la crocette est déviée (b) le guide doit faire un angle aigu pour aller dans la descendante alors que arrivant par le tronc artériel brachiocephalique l'angle est plus favorable.



l'avant-bras et la main au moment soit de l'anesthésie mais surtout de la ponction. Ce risque est difficilement évitable étant donné les rapports anatomiques. Il faut donc éviter les piqûres répétitives (Fig. 2).

Il peut se faire que l'on ait un jet de sang bien rythmique mais que l'on ne puisse pousser de quelques millimètres le trocart, ou que le guide bute quand on l'introduit. Il s'agit alors de la scapulaire inférieure et il faut recommencer la ponction après avoir comprimé soigneusement cette artère.

Le cheminement du guide peut être stoppé, ou dans une boucle artérielle (coudé de la sous-clavière, boucle du tronc artériel brachiocephalique) — il faut faire quelques manœuvres prudentes, uniquement avec la partie souple du guide, boucle si possible et ne pas insister — ou par une sténose.

Il peut être impossible de faire passer le guide dans la partie descendante de la crosse. Par voie gauche, si l'orte est déroulée, si la sous-clavière fait un angle aigu avec la crosse le guide ne pourra remonter dans la crosse (Fig. 3). Il faut essayer alors un guide très courbé à son extrémité qui peut réussir à franchir le triquet en brionnette. Par voie droite on peut passer dans l'orte descendante. Nous le faisons lorsqu'il existe une sténose sous-clavière gauche ou lorsque la crosse nous paraît déroulée, c'est à dire à partir d'un certain âge (50 ans environ). En effet le passage de la sonde dans l'orte descendante est moins difficile par la voie droite que par la voie gauche dès que la crosse aortique se surélève et s'allonge.

Applications, résultats et critique de la méthode

En total, 196 applications de l'exploration ont été faites : aorte aortique et vaisseaux du cou 26, aorte 57, digestives 64, sélectives rénales 48 et coronaires une. Pour certains patients la aorte et l'orte étaient explorées pendant le même examen.



Fig. 4 Retrograde axillaire pour injection de la nœcserque inférieure chez un patient atteignant de rectocolite hémorragique



Fig. 5 Retrograde axillaire pour injection de l'artère hépatique la sonde est au-delà de l'artère gastroduodénale (Étude du foie d'un sujet éthylé)

Inconvénients La ponction axillaire est plus longue que celle de l'artère fémorale. Le plexus brachial est une gêne certaine. Les échecs de cathétérisme sont plus fréquents par cette voie mais il faut considérer que nous n'avons plus de contre-indication du fait de l'état artériel partant nous avons beaucoup de patients qui ne pouvant subir un cathétérisme fémoral nous sont adressés.

Sur 500 cathétérismes artériels nous avons fait 210 par voies axillaires. Sur 28 échecs la ponction était impossible (5), on ne passait pas (10) — la sous-clavière (9) et le tronc artériel brachio-céphalique (1) — et la sonde ne pouvait pas tourner dans la crosse pour aller dans la descendante (13).

Pour ce dernier lot l'examen est nul s'il s'agit de faire une sélective. Il est réalisable pour une gerbe pour les vaisseaux du cou pour une aorte simple et on injecte alors dans la crosse. Pour les aortographies on peut donc considérer les échecs à 15 ce qui fait 7%. C'est encore beaucoup par rapport à la voie fémorale. Depuis que nous faisons des voies axillaires droites le passage dans la



Fig. 6. Retrograde axillaire pour injection de l'artère hépatique et gastroduodénale. Il existe un diaphragme sur l'hépatique et une sténose de la gastroduodénale. La gastroepiploïque injecte l'artère splénique (Sujet suspect d'atteinte pancréatique).

crosse, quand elle est déroulée, se fait de façon plus facile. Une seule fois pour cette voie nous n'avons pas pu franchir la crosse aortique.

Roi sur 475 examens avait 46 échecs, à peu près 10 %. Nous pensons que notre proportion d'échecs diminuera avec le nombre d'explorations.

Avantages "Il y a moins de manchots que de cul de jatte", ce qui prouve que les artères des membres supérieurs sont moins souvent altérées par l'athérome. Corollaire de la proposition, sus-jacente, le passage est presque toujours possible par l'axillaire, alors que les fémorales ne battent plus. Autre corollaire de la proposition première est que le risque est moindre. Artères moins altérées et la revascularisation du membre supérieur est moins précaire en cas de thrombose.

Il s'agit pour notre part d'une méthode ambulatoire. Le patient peut rentrer chez lui 2 à 3 heures après l'examen. Il peut contrôler lui-même, de la main opposée, son aisselle.

L'avantage le plus déterminant est dû à la facilité beaucoup plus grande des sélectives digestives (BOIJSEN 1966).

Du fait du trajet des artères et de leur inclinaison sur l'aorte, le cathétérisme descendant va dans le bon sens, il n'y a pas à faire de crocheteur de l'ostium.

comme dans le catheterisme ascendant crochetaje qui interdit presque toujours de penetrer dans l'artere au dela du premier centimetre on voit sur les radiographies combien la courbe du catheter dans la penetration est naturelle non forcee Ceci est valable non seulement pour les arteres abdominales mais pour les arteres pelviennes et celles du membre inferieur

Incidents Nous avons eu sept incidents Trois incidents etaient des traumatismes nerveux une dysesthesie des doigts definitive un trouble combine, moteur et sensitif de la pince pouce index mais partiel une paralysie du median par defaut de surveillance l'hematome s'est constitue dans les jours qui ont suivi l'examen chez un sujet au psychisme a ce point fruste que c'est a l'occasion d'une brulure grave de la main que l'on a decouvert la paralysie et sa cause un mois apres la ponction cet accident n'est pas entierement imputable a la methode Nous avons eu deux hematomes sans gravite Deux fois nous avons fait une dissection de la sous-claviere, le guide cheminant dans la paroi arterielle aucune manifestation n'a suivi cette dissection et l'examen a pu etre mene a bien

Il est interessant a noter que nous n'avons jamais eu de thrombose le seul geste chirurgical que nous avons provoque est une decouverte sous anesthésie locale de l'artere qui s'est remise a battre apres infiltration de Syncaine

ROY (1965) fait etat sur 475 examens de 4 cas de traumatismes nerveux, dont les signes etaient presents un an apres et 11 cas de traumatismes arteriels — huit de disparition du pouls et trois qui necessitaient une thrombectomie Les autres sont amehores 7 cas d'hematomes et une fois drainage chirurgical

STAAL et coll (1966) sur 21 examens par voie axillaire fait etat de 7 lesions nerveuses deux durables DUBRICK et coll (1967) sur 305 par voie axillaire avait deux types d'accidents nerveux — l'un benign engourdissement dans le territoire du cubital et l'autre plus grave du au saignement dans la gaine neuromusculaire comprimant les branches du plexus brachial

NEWTON (1963) sur 160 cas n'a pas eu d'accident et BOIJSEN (1966) sur 70 examens par voie axillaire a eu un cas de thrombose axillaire

Conclusion

Nous ne serons que citer les *methodes indirectes d'opacification arterielle par voie intra lamineuse* (CLSMANO & GALLAGHER 1963 STEINBERG et coll 1959, VIALLET et coll 1959) Cette technique est reservee aux nourrissons et aux impossibilites arterielles

Les *techniques de ponction directe des gros vaisseaux* aorte (DOS SANTOS et coll 1931 LEMMON et coll 1959 WICKBOM 1952) et sous-claviere (MORRIS

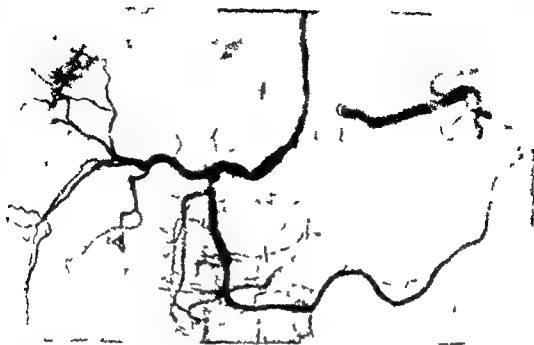


Fig. 6. Retrograde axillaire pour injection de l'artère hépatique et gastroduodénale. Il existe un diaphragme sous l'hépatique et une sténose de la gastroduodénale. La gastropéplique ne jette l'artère splénique. (Sujet suspect d'atteinte pancréatique)

croisée, quand elle est déroulée, se fait de façon plus facile. Une seule fois pour cette voie nous n'avons pas pu franchir la croisée aortique.

Sur 475 examens, nous avons eu 46 échecs, à peu près 10 %. Nous pensons que notre proportion d'échecs diminuera avec le nombre d'explorations.

Avantages. Il y a moins de manchots que de cul de jatte, ce qui prouve que les artères des membres supérieurs sont moins souvent altérées par l'athérome. Corollaire de la proposition sus-jacente, le passage est presque toujours possible par l'axillaire, alors que les femorales ne battent plus. Autre corollaire de la proposition première est que le risque est moindre : artères moins altérées et la revascularisation du membre supérieur est moins précieuse en cas de thrombose.

Il s'agit pour notre part d'une méthode ambulatoire. Le patient peut rentrer chez lui 2 à 3 heures après l'examen. Il peut contrôler lui-même de la main opposée, son aisselle.

L'avantage le plus déterminant est dû à la facilité beaucoup plus grande des sélectives digestives (BOIJSEN 1966).

Du fait du trajet des artères et de leur inclinaison sur l'aorte, le cathétérisme descendant va dans le bon sens, il n'y a pas à faire de crochetage de l'ostium.

Tableau

Les accidents des différents auteurs ayant publié la méthode

Auteurs	ROY	STAAL	DUBRICK	NEWTON	BOIJSEN	HUGLET
Cas	475	21	305	160	70	210
Échecs	46	—	—	—	—	28
Lésion artérielle	3	—	—	—	1	—
Lésion nerveuse	4	2	+	—	—	3

Vous ne tenons compte que des lésions permanentes ou ayant nécessité une correction chirurgicale
 DUBRICK parle d'accidents nerveux mais ne donne pas de chiffre

femorales aggrave le risque, pour les anévrysmes ou thromboses de l'aorte abdominale, et enfin, l'indication est préférable lorsqu'il s'agit d'un malade que l'on ne peut pas hospitaliser

Le cathétérisme artériel par voie axillaire est plus difficile mais il permet des investigations qui ne pourraient être faites autrement, il autorise des injections hyperselectives (BOIJSEN) Il faut connaître les risques nerveux encourus mais ceux-ci doivent pouvoir être évités

RÉSUMÉ

Les auteurs argumentent l'intérêt de la voie axillaire pour introduire un cathéter susceptible de faire des artériographies de l'aorte ou de ses branches. La voie axillaire est plus difficile elle peut entraîner des blessures du plexus brachial avec séquelles définitives mais elle autorise des examens chez des patients dont les artères femorales ne battent plus et permet des artériographies hyperselectives des artères digestives.

SUMMARY

The value of catheterization via the axillary artery for angiography of the aorta and its branches is discussed. Though approach via the axillary artery is comparatively difficult and can lead to injury of the brachial plexus with consequent sequelae the method may be recommended in the examination of patients having non-pulsating femoral arteries and it also permits highly selective angiography of the digestive arteries.

ZUSAMMENFASSUNG

Der Wert der Katheterisierung
 und deren Äste
 relativ schwierige

Aus: brachialis mit den entsprechenden

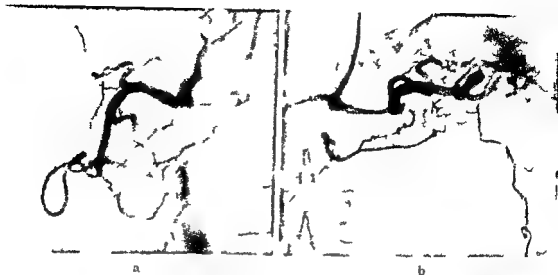


Fig. 7. Rétrograde pour l'étude des vaisseaux rénaux : a) cathéterisation de l'artère rénale par l'artère abdominale (incidence de 3/4) b) et c) Obliteration de l'axe spléno-renal rétrograde par l'artère pour visualiser la veine porte artère du corps et de la queue du pancréas



1959) nous paraissent plus périlleuses que les techniques actuelles. Elles ont eu un grand mérite avant l'innovation de Seldinger.

Technique de contre courant à distance (CASTELLANOS & PEREIRAS 1950 MARSHALL & LINC 1963 BAIRD et coll 1965 ECOFFIER et coll 1964 THIERRY et coll 1966). Elles sont faciles à réaliser présentant un minimum de risques. Elles peuvent être employées pour l'exploration des vaisseaux du cou et de la gorge.

Le cathétérisme fémoral (LILIFQUIST & HELLSTROM 1965). Il est plus facile, on doit lui préférer la voie axillaire pour toute artériographie qui se veut très sélective (CFCILLE et coll 1965 CARON 1965 KLAUS & BRON 1966). La splénique, hépatique et gastro duodénale, mésentérique inférieure (ne connaît pas d'échec par voie haute), les artères lombaires, lorsque l'état des artères

- THIERRY A, EYSETTE, BIGAY et coll Artériographie vertébrale par voie humérale rétrograde
J Radiol 47 (1966), 564
- VIALLET P, SENDRA L, CHEVROT L ■ coll Angiocardiopneumographie élargie Méthode
d'opacification vasculaire générale par voie veineuse Masson et Cie, Paris 1959
- WICKBOM I Thoracic aortography after direct puncture of the aorta from the jugulum Acta
radiol 38 (1952), 343

Folgen führen kann wird diese Methode für die Untersuchung solcher Patienten empfohlen deren Femoralarterien nicht pulsieren. Diese Methode ermöglicht ausserdem eine hyperselektive Angiographie der Arterien des Verdauungstraktes.

BIBLIOGRAPHIE

- BAIRD R, LAJAYONTAFR M, MURTAGH F and SCOTT M Percutaneous retrograde brachial arteriography *Amer J Roentgenol* 94 (1965), 14
- BOIJSEN E Selective visceral angiography using a percutaneous axillary technique *Brit J Radiol* 39 (1966), 411
- CARON J Insuffisance vasculaire cérébrale par lésions athéromateuses des vaisseaux issus de la crosse aortique *J Radiol* 46 (1965), 919
- CASTELLANOS A and PEREIRAS R Retrograde or counter current aortography *Amer J Roentgenol* 63 (1950), 559
- CECILLI J P, BONET G, LFLIEU G et coll Artériographie vertébrale par voie axillaire avec sonde bouchée *J Radiol* 46 (1965), 903
- CUSMANO J and GALLAGHER J Single arm percutaneous intravenous aortography *Amer J Roentgenol* 89 (1963), 269
- DOS SANTOS R, LAMAS A et CALDAS J P Artériographie des membres et de l'aorte abdominale Masson et Cie, Paris 1931
- DUBRICK S, MASLAND W and MISHKIN M Brachial plexus injury following axillary artery puncture *Radiology* 88 (1967), 271
- ECOIFFIER J, BORIS M et BOLROUES M Artériographie vertébrale par voie axillaire *Ann Radiol* 7 (1961), 189
- GENSINI G G and ECKER A Percutaneous aorto cerebral angiography *Radiology* 75 (1960) 885
- KLAUS M and BROWN M Selective visceral and total abdominal arteriography via the left axillary artery in the older age group *Amer J Roentgenol* 97 (1966) 433
- LEMMON W M, LEHMAN J S and BOYER R A Suprasternal transaortic coronary arteriography *Circulation* 19 (1959), 47
- LILIEQUIST H and HELLSTROM L Technique of aortocervical angiography *Acta radiol* Diagnosis 3 (1965), 17
- MARSHALL T R and LING J T Direct percutaneous non catheter left and right brachial angiography *Radiology* 80 (1963), 258
- MORRIS L Artériographie démonstration of vertebral artery with special reference to percutaneous subclavian puncture *Brit J Radiol* 32 (1959), 673
- NEWTON T H Axillary artery approach to arteriography of aorta and its branches *Amer J Roentgenol* 98 (1963) 275
- OLMAN P Percutaneous selective angiography of main branches of aorta *Acta radiol* 45 (1956) 1
- ROY P Percutaneous catheterisation via the axillary artery *Amer J Roentgenol* 94 (1965) 1
- SELDINGER S I Catheter replacement of needle in percutaneous arteriography new technique *Acta radiol* 39 (1953) 368
- STAAL A, VAN VOORTHUISSEN A E and VAN DIJK L M Neurological complication following arterial catheterisation by the axillary approach *Brit J Radiol* 39 (1966), 117
- STEINBERG I, FINBY N and EVANS J A safe and practical intravenous method for abdominal aortography, peripheral arteriography and cerebral angiography *Amer J Roentgenol* 82 (1959), 758

1. **Project Overview:** The project aims to develop a comprehensive system for managing the company's financial data, including budgeting, accounting, and reporting. The system will be developed using a modular architecture, allowing for scalability and flexibility.

2. **Key Objectives:**

- Improve financial data accuracy and consistency.
- Streamline the budgeting and accounting processes.
- Enhance reporting capabilities and provide real-time insights.
- Ensure data security and compliance with relevant regulations.

3. **Scope of Work:** The project will cover the following areas:

- Requirement gathering and analysis.
- System design and architecture.
- Development and testing of modules.
- Deployment and user training.
- Ongoing support and maintenance.

4. **Timeline and Milestones:** The project is scheduled to start in January 2024 and is expected to be completed by June 2024. Key milestones include:

- Requirement gathering and analysis (January - February).
- System design and architecture (February - March).
- Development and testing of modules (March - May).
- Deployment and user training (May - June).

5. **Resources:** The project team consists of the following members:

- Project Manager: [Name]
- Business Analysts: [Name]
- System Architects: [Name]
- Developers: [Name]
- Testers: [Name]
- Trainers: [Name]

6. **Risks and Mitigation:**

- Risk:** Scope creep.
- Mitigation:** Regular communication and change management.
- Risk:** Resource availability.
- Mitigation:** Cross-training and backup resources.
- Risk:** Data security.
- Mitigation:** Robust security measures and regular audits.

7. **Conclusion:** This project is a critical initiative for the company, aimed at improving financial management and reporting. By successfully implementing the system, the company will achieve its goals of increased accuracy, streamlined processes, and enhanced reporting capabilities.

Folgen führen kann wird diese Methode für die Untersuchung solcher Patienten empfohlen deren Femoralarterien nicht pulsieren Diese Methode ermöglicht ausserdem eine , hyper selektive Angiographie der Arterien des Verdauungstraktes

BIBLIOGRAPHIE

- BAIRD R, LAJAYOWITZER M, MURTAGL F and SCOTT M Percutaneous retrograde brachial arteriography *Amer J Roentgenol* 91 (1965), 14
- BOIJSEN E Selective visceral angiography using a percutaneous axillary technique *Brit J Radiol* 39 (1966), 114
- CARON J Insuffisance vasculaire cérébrale par lésions athéromateuses des vaisseaux issus de la crosse aortique *J Radiol* 46 (1965), 919
- CASTELLANOS A and PEREIRAS R Retrograde or counter current aortography *Amer J Roentgenol* 63 (1950), 559
- CECILLE J P, BONTE G, LFIU G et coll Artériographie vertébrale par voie axillaire avec sonde bouchée *J Radiol* 46 (1965) 903
- CUSMANO J and GALLAGHER J Single arm percutaneous intravenous aortography *Amer J Roentgenol* 100 (1963) 269
- DOS SANTOS R, LAMAS A et CALDAS J P Artériographie des membres et de l'aorte abdominale Masson et Cie Paris 1931
- DUBRICK S, MASLAND W and MISHKIN M Brachial plexus injury following axillary artery puncture *Radiology* 88 (1967), 271
- ECHOFFIER J, BORIES M et BOURCUPS M Artériographie vertébrale par voie axillaire *Ann Radiol* 7 (1964), 189
- GENSINI G G and ECKER A Percutaneous aorto cerebral angiography *Radiology* 75 (1960) 885
- KLAUS M and BROW M Selective visceral and total abdominal arteriography via the left axillary artery in the older age group *Amer J Roentgenol* 97 (1966), 433
- LEMMON W M, LEHMAN J S and BOYER R A Suprasternal transaortic coronary arteriography *Circulation* 19 (1959), 47
- LILIEQUIST B and HELLSTROM L Technique of aortocervical angiography *Acta radiol* Diagnosis 3 (1965), 17
- MARSHALL T R and LING J T Direct percutaneous non catheter left and right brachial angiography *Radiology* 80 (1963) 258
- MORRIS L Arteriographic demonstration of vertebral artery with special reference to percutaneous subclavian puncture *Brit J Radiol* 32 (1959), 673
- NEWTON T H Axillary artery approach to arteriography of aorta and its branches *Amer J Roentgenol* 98 (1963), 275
- ÖDMAN P Percutaneous selective angiography of main branches of aorta *Acta radiol* 45 (1956), 1
- ROY P Percutaneous catheterisation via the axillary artery *Amer J Roentgenol* 94 (1965) 1
- SELDINGER S I Catheter replacement of needle in percutaneous arteriography new technique *Acta radiol* 39 (1953), 368
- STAAL A, VAN VOORTHUIZEN A E and VAN DIJK L M Neurological complication following arterial catheterisation by the axillary approach *Brit J Radiol* 39 (1966), 117
- STEINBERG I, FINBY N and EVANS J A A safe and practical intravenous method for abdominal aortography, peripheral arteriography and cerebral angiography *Amer J Roentgenol* 82 (1959), 758

- THIERRY A., EYSSETTE, BIGAY et coll. Artériographie vertébrale par voie humérale rétrograde
J Radiol 47 (1966), 564
- VIALLET P., SENDRA L., CHEVROT L. et coll. Angiocardiopneumographie élargie Méthode
d'opacification vasculaire générale par voie veineuse Masson et Cie, Paris 1959
- WICKBOM I. Thoracic aortography after direct puncture of the aorta from the jugulum Acta
radiol 38 (1952), 343

SIMPLIFIED SENSITOMETRY

by

OVE MATSSON

It is important in the selection of radiographic materials, screen-film combinations and processing techniques to have available the characteristic curves, describing the relation exposure to density and providing all the information required. Such curves are obtained by plotting the densities recorded against the common logarithm of exposures, the latter being the product of radiographic intensity and exposure time.

A simple practical test for a comparison of two radiographic materials may be made by exposing both materials in an equivalent manner, stepwise increasing the exposure by employing a step wedge or some other means. The comparison of densities may be made with the naked eye or the values may be read on a densitometer. Only an approximate evaluation can be made in this way.

When step wedges are used, the densities can be plotted versus step thickness. Step wedges suitable for radiography have been described e.g. by CORNEY & SEEMAN (1947) and SEEMAN & ROTH (1960). The latter described in 1962 a phantom for industrial radiography.

Mistakes can be made in the comparison of films with a limited range of densities, if the films differ in contrast the characteristic curves intersect and the result may appear confusing when comparing the densities at different levels. A material may give a better dose response at one level compared to another. A series of representative steps over the whole range is necessary.

Submitted for publication 5 June 1969



Fig. 1 A sector wheel (with a common ratio of 2)

The problem of evaluating photographic qualities often arise in a roentgen department. New deliveries of film or processing material, improved screens etc demand accurate quality control. Sensitometry is too complicated to be carried out in an ordinary roentgen department since it may be difficult to achieve the required accuracy in exposures and obtain an extensive range of exposures. According to HERCOCK (1963) an exposure range of at least 100:1 is required for testing roentgen materials but a range of 1 000:1 is preferable for comparative testing of materials that differ considerably in speed. A suitable ratio is $\sqrt{2}$ or 2. For extreme values a change of intensity may be necessary, still complicating the procedure. A sector wheel made of lead may facilitate the exposure, but stroboscopic effects caused by the intensity variation of the radiation from the alternating current may be disturbing. A sector wheel with a common ratio of 2 is shown in Fig. 1. The 'intermittence effect' may also influence the result — a phenomenon that appears when an exposure time is divided into many small periods — the total effect is lower than expected from the mathematical sum. The reciprocity law failures may disturb the results in the range of exposures from some milliseconds to several seconds. These failures have a certain practical importance in radiology (FRANTZELL 1950).

A simple technique for roentgen sensitometry with ordinary equipment of a roentgen department would obviously be of great value.

Using a sequence of only three exposures in combination with a simple step wedge, all the levels of density required for a useful correlation of densities to exposures can be produced. There is no critical limit to the dimensions of the step wedge. The author has used plates of acrylate 10 mm in thickness and the number of steps has been varied from 10 to 15.

With a fixed exposure setting providing a good exactness, exposure relations of 1 2 4 may be obtained by a repetition of single exposures in the required number, uncovering the film stepwise between the exposures.

Three exposures give three density values for each density level, each group forms an incomplete portion of a density curve. A complete series of recorded values is shown in Fig 2. If the wedge steps are not very different superimposition of the curves of various steps can easily be made, translucent paper will assist registration. The result will be a characteristic curve with a great number of recorded values.

The curve may also be constructed in a more exact way. The series of incomplete curves represent the correlation exposure to density in each step, the sequence of exposure values is logarithmic (1—2—4). From these curves the interval horizontally along the X-axis at each level can be estimated — the effective difference in intensity from step to step. It is then possible to build up a complete curve with all density values plotted against the relative exposure intensities calculated (Fig 3a). The curve refers to a standard roentgen film exposed with screens and processed in a slow developing machine, a curve representing a roentgen film for industrial purpose exposed with screens is shown in Fig 3b. The fact that most roentgen films possess high contrast means steep gradation, a long straight part of the curve will facilitate the building of its final form. The limited range of exposure eliminates the risk of reciprocity law failures and the type of exposure means practically no risk of an intermittence effect.

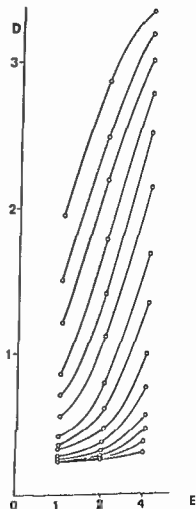


Fig 2 A complete series of recorded values from a test. Each step is represented by an incomplete density curve.

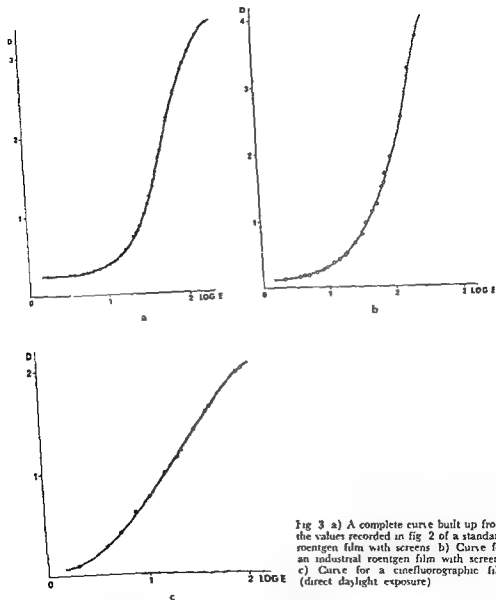


Fig 3 a) A complete curve built up from the values recorded in fig 2 of a standard roentgen film with screens b) Curve for an industrial roentgen film with screens c) Curve for a cinefluorographic film (direct daylight exposure)

From a practical viewpoint the method is realistic as unfiltered radiation never exists in radiography, the higher densities representing areas with low tissue filtration and the low density areas recordings of the highly absorbing parts of the

Using a sequence of only three exposures in combination with a simple step wedge, all the levels of density required for a useful correlation of densities to exposures can be produced. There is no critical limit to the dimensions of the step wedge. The author has used plates of acrylate 10 mm in thickness and the number of steps has been varied from 10 to 15.

With a fixed exposure setting providing a good exactness, exposure relations of 1:2:4 may be obtained by a repetition of single exposures in the required number, uncovering the film stepwise between the exposures.

Three exposures give three density values for each density level, each group forms an incomplete portion of a density curve. A complete series of recorded values is shown in Fig. 2. If the wedge steps are not very different, superimposition of the curves of various steps can easily be made, translucent paper will assist registration. The result will be a characteristic curve with a great number of recorded values.

The curve may also be constructed in a more exact way. The series of incomplete curves represent the correlation exposure to density in each step, the sequence of exposure values is logarithmic (1—2—4). From these curves the interval horizontally along the X-axis at each level can be estimated — the effective difference in intensity from step to step. It is then possible to build up a complete curve with all density values plotted against the relative exposure intensities calculated (Fig. 3a). The curve refers to a standard roentgen film exposed with screens and processed in a slow developing machine, a curve representing a roentgen film for industrial purpose exposed with screens is shown in Fig. 3b. The fact that most roentgen films possess high contrast means steep gradation, a long straight part of the curve will facilitate the building of its final form. The limited range of exposure eliminates the risk of reciprocity law failures and the type of exposure means practically no risk of an intermittence effect.

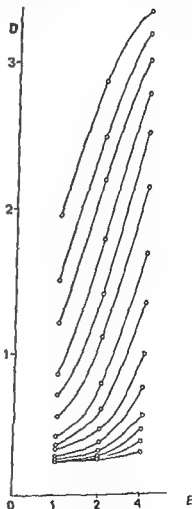


Fig. 2. A complete series of recorded values from a test. Each step is represented by an incomplete density curve.

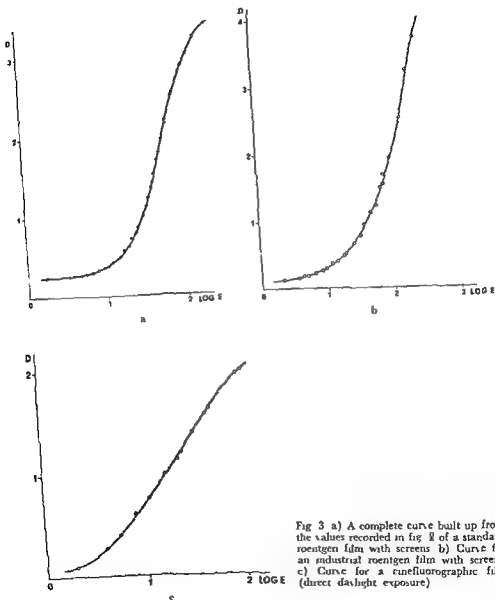


Fig 3 a) A complete curve built up from the values recorded in fig 2 of a standard roentgen film with screens b) Curve for an industrial roentgen film with screens c) Curve for a cinefluorographic film (direct daylight exposure)

From a practical viewpoint the method is realistic as unfiltered radiation never exists in radiography, the higher densities representing areas with low tissue filtration and the low density areas recordings of the highly absorbing parts of the

object. The true recording of contrast is obtained for each step of absorption level. The final curve produces complete information on the practical qualities of the radiographic material tested.

The principle has also been utilized for testing cinefluorographic film. This is exposed in an ordinary camera with a conventional shutter mechanism. One, two and four exposures are given on different frames, the object being a screen with various steps in plain grey under uniform illumination. A curve obtained in this way is shown in Fig. 3c.

SUMMARY

A method of simplified sensitometry of radiographic material is presented. No special apparatus is required.

ZUSAMMENFASSUNG

Eine Methode für die vereinfachte Sensitometrie von Röntgenfilmen wird vorgelegt. Keine Spezialapparatur ist erforderlich.

RÉSUMÉ

Présentation d'une méthode de sensitométrie simplifiée du matériel radiographique. Elle ne nécessite pas d'appareil spécial.

REFERENCES

- CORNEY G. M. and SEFMAN H. E. A logarithmic step tablet for X rays. Non destructive testing 6 (1947), 27.
- FRANTZELL A. The practical roentgenographic importance of reciprocity law failures. Acta radiol. 34 (1950), 6.
- HERCOCK R. J. X-ray sensitometry. X-ray Focus 4 (1963), 2.
- SEEMANN H. F. and ROTH B. New stepped wedges for radiography. Acta radiol. 53 (1960) 215.
- — A new stepped wedge design for industrial radiography. Non destructive testing 20 (1962), 37.

TRAUMATIC ARTERIAL SPASM

An angiographic study in rabbits

by

JAN GUTHLIN and TORD OLIN

Catheterization of arteries and veins is nowadays a common procedure in roentgenology, cardiology, clinical physiology, nephrology and surgery. The procedure is sometimes complicated by spasm with ischemia, and intimal lesions with ensuing thrombosis may follow. Arterial spasm has earlier been a problem, mainly during war surgery, as described by KROH (1917), MAARS (1919), VON KUTTNER & BARUCH (1920), GRIFFITHS (1940), COHEN (1941, 1944) and DE BAKEY & SIMONE (1946). Penetrating injuries causing spasm under more ordinary conditions were described by FREEMAN (1949), and following trauma in general by KYLLÖNEN (1966). Arterial spasm in connection with puncture and catheterization has been reported by several authors, e.g. RADNER (1951), LINDBOM (1957), WICKBOM & BARTLEY (1957), ELFTV (1960), SCHECHTER (1963), SHILTON (1964) and LEVIN et coll (1967). The same conditions after vascular surgery were demonstrated by GISENIUS (1950). Arterial spasm caused by venous puncture was considered by SUTTON (1952), NARSELI & JONES (1963) and GARROW & KISHNICK (1965). Fractures as a cause of spasm

From the Laboratory of Experimental Roentgenology, the University Hospital, Lund, Sweden. This work was supported by grant No B69 23X 605-03 from the Swedish Medical Research Council. Submitted for publication 16 May 1969.



Fig 1 a) Normal angiogram of the left femoral artery. b) Angiogram one hour after puncture of the femoral artery with a small cannula during fluoroscopy. Spasm of the artery and its branches.

were investigated by e.g. MONTGOMERY & IRFAND (1935), LERICHE (1939), GRIFFITHS (1940), COHEN (1941, 1944), CONSOLE (1948), KULOWSKI (1955) and WHOLEY & BOCHER (1967). Experimentally provoked spasm in animals has been studied in the arteries of the ear of the rabbit by GRANT (1929), in the arteries of the hindlimbs by BARNES & TRUETA (1942), in the femoral arteries of the rabbit and the cat by KINMONTH *et coll.* (1949) and KINMONTH (1952) and in the femoral vessels of the dog by SCHWARTZ *et coll.* (1961).

The effect of trauma applied either directly to the artery or to its adjacent nerves appears to have remained uninvestigated and no systematic study of the prevention is recorded in the literature. These considerations prompted the present study.

Material and Methods Thirty-five rabbits were examined under superficial general anaesthesia with intravenous Mebumalnatrrium (pentobarbitone sodium ACO, Sweden) except in one rabbit in which ether on an open mask was used. A radiopaque polythene catheter (OPP 60, Portex, England) (outer diameter 1.15 mm, inner diameter 0.75 mm) was introduced into the right femoral artery under local anaesthesia. The tapered and suitably moulded up of the catheter was placed in the left common iliac, the left subclavian and the right common carotid arteries, respectively, by the technique of ADAMS *et coll.* (1965). Angiography was performed with Iopaque Cerebral (meglumine metrizoate, NFN, Nyco, Norway) injected at a constant rate with an infusion machine. The film focus distance was 90 cm. An incision was made in the left groin or the left axilla, so that the artery with accompanying nerves could be seen through the fasciae. The common carotid artery, however, due to its deep position, was always dissected free and further angiography performed. The artery and the accompanying nerves were then injured by forceps, or by

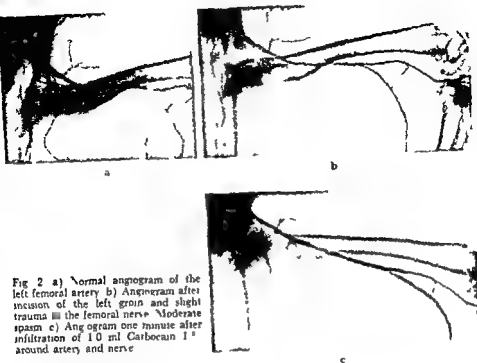


Fig 2 a) Normal angiogram of the left femoral artery b) Angiogram after incision of the left groin and slight trauma ■ the femoral nerve Moderate spasm c) Angiogram one minute after infiltration of 10 ml Carbocain 1% around artery and nerve

applying a thread around the artery and pulling it to and fro, or by puncturing the artery with a fine cannula. Repeat angiograms were then obtained. Local anesthesia was sometimes infiltrated around the artery and the nerves before the trauma, but in other experiments it was applied following it. The effect of vasoactive drugs administered through the catheter before and after the injury was also studied.

Results

Trauma of the *femoral artery and nerve* caused arterial spasm to a varying degree in nine experiments. Puncture of the artery always produced severe contraction (Fig 1 a and b) whereas cautious free dissection inflicted only slight spasm (Fig 2 a, b and c). Non perforating trauma always resulted in less constriction than did puncture. The spasm in advanced cases extended high up in the external iliac and far down in the popliteal artery, it arose soon after the trauma and developed fully in 1 to 2 minutes. When no further procedures were taken, the contraction diminished to some degree although it was still



2

The first of these is the fact that the design is not a simple one, but a complex one, involving a large number of lines and curves. This suggests that the design is not a simple one, but a complex one, involving a large number of lines and curves.

The second of these is the fact that the design is not a simple one, but a complex one, involving a large number of lines and curves. This suggests that the design is not a simple one, but a complex one, involving a large number of lines and curves.

The third of these is the fact that the design is not a simple one, but a complex one, involving a large number of lines and curves. This suggests that the design is not a simple one, but a complex one, involving a large number of lines and curves.

The fourth of these is the fact that the design is not a simple one, but a complex one, involving a large number of lines and curves. This suggests that the design is not a simple one, but a complex one, involving a large number of lines and curves.

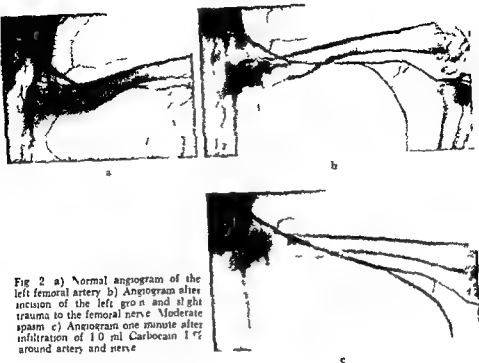


Fig 2 a) Normal angiogram of the left femoral artery b) Angiogram after incision of the left groin and slight trauma to the femoral nerve. Moderate spasm c) Angiogram one minute after infiltration of 10 ml Carbocain 1% around artery and nerve

applying a thread around the artery and pulling it to and fro, or by puncturing the artery with a fine cannula. Repeat angiograms were then obtained. Local anesthesia was sometimes infiltrated around the artery and the nerves before the trauma, but in other experiments it was applied following it. The effect of vasoactive drugs administered through the catheter before and after the injury was also studied.

Results

Trauma of the *femoral artery and nerve* caused arterial spasm to a varying degree in nine experiments. Puncture of the artery always produced severe contraction (Fig 1 a and b) whereas *cautious free dissection inflicted only slight spasm* (Fig 2 a, b and c). Non perforating trauma always resulted in less constriction than did puncture. The spasm in advanced cases extended high up in the external iliac and far down in the popliteal artery, it arose soon after the trauma and developed fully in 1 to 2 minutes. When no further procedures were taken, the contraction diminished to some degree although it was still



Fig 3 a) Normal angiogram of left femoral artery b) Angiogram after pinching of the femoral nerve Slight spasm

evident for some hours. The trauma in 16 experiments was applied only to the femoral nerve, the constriction developed was usually less marked than that after pure arterial stimulation (Fig 3 a and b). Cutting of the femoral nerve failed to change the calibre of the artery but segmental spasm in the saphenous artery sometimes appeared.

The brachial artery and nerve were pinched or punctured in 20 studies. The arrangement of the brachial plexus made it almost impossible to separate the artery and the nerves and even cautious free dissection resulted in marked spasm (Fig 4 a, b, c and d) in the brachial artery over some centimeters. Puncture caused more spasm than pinching.

Trauma of the *common carotid artery* in ten experiments produced no or only slight spasm (Fig 5 a and b). Even repeat puncture produced only a slight contraction. Free dissection of the internal carotid artery, however, resulted in spasm.

Treatment of spasm in the brachial and femoral arteries. The effect of local anesthesia was studied on thirty occasions. If the anesthesia were correctly applied (locally and proximally to the trauma) with Carbocain 1 % or Axylocain 1 %, no or only slight spasm appeared after the trauma. When the local anesthetic agent contained epinephrine (5 $\mu\text{g}/\text{ml}$), moderate contraction appeared with the anesthetic in nine experiments. Pure epinephrine (40 $\mu\text{g}/\text{ml}$) produced marked spasm (Fig 6 a and b). When local anesthesia was applied following trauma in ten studies, the already established spasm diminished considerably (Figs 2 b and c, 5 a and b, 7 a and b).

α -receptor blocking agents. Three drugs have been tested. Regitin (Phentolaminum INN, Ciba, Switzerland) was investigated in four experiments in which 0.25 to 0.5 mg through the catheter relaxed the spasm in one minute.

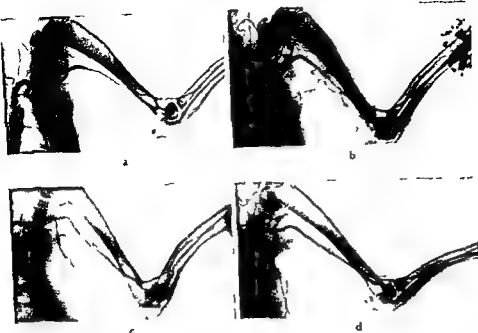


Fig 4 a) Angiogram after free dissection of the left brachial artery. Marked spasm b) Angiogram six minutes after injection of 6 mg papaverine through the catheter. Some relief of spasm c) Angiogram after free dissection of the left brachial artery. Moderate spasm d) Angiogram one minute after injection through the catheter of 0.5 mg Regitin. Relief of spasm

(Fig 4 a and b), although in one case slight contraction remained. The dilating effect lasted more than 10 minutes. Hydergin (Dihydroergotamin, Sandoz, Switzerland) in a dose of 0.03 mg in two experiments caused some diminution of the spasm. Dibenzylamine (Phenoxybenzamine, Kline & French Lab, England) in a dose of 10 mg in two studies gave a good but incomplete relief.

β -receptor stimulating agents Duvadilan (Isosuprinum INN, Ferrosan, Sweden) in doses of 0.05 to 0.6 mg was investigated in eleven experiments. A dose of 0.125 mg was always sufficient to abolish spasm and in most cases the artery was wider after Duvadilan than in control angiography (Fig 8 a and b). The full effect was reached after 30 seconds and remained for at least 10 minutes, slight vasoconstriction returned in two experiments. Arterial blood pressure, pulse pressure and heart rate were controlled in six studies and the deviation from normal was minimal after doses of 0.05 to 0.25 mg. Vasculat Bamethanum NFN, Boehringer/Ingelheim, West Germany) was tested three times in doses of 2.5 to 10 mg with almost no effect on spasm.



Fig 5 a) Angiogram of the right common carotid artery after pulling the artery to and fro ten times with a thread. Almost no spasm. b) Angiogram five minutes after local application of 0.8 ml Celocain 1%. Moderate dilatation of the artery and no spasm.

β -receptor blocking agents Inderal (Propranololum INN, ICI, England) was studied in three experiments in doses of 0.5 to 30 mg through the catheter or infiltrated around the vessel. No effect on spasm was evident.

Ganglion blocking agents Arfonad (Trimetaphanum INN, Roche, Switzerland) was investigated in 12 experiments with control of arterial blood pressure, the doses varying widely due to tachyphylaxis. The drug was given intraarterially or intravenously. When the arterial blood pressure was around 40 mm Hg angiography was followed by films during the return of the blood pressure to normal. In no case was there any effect on spasm. Arfonad infusion during the trauma failed to prevent spasm. Papaverine (Papaverinum NFN, ACO Sweden) was tested seven times in doses of 0.25 to 60 mg. It more or less abolished spasm (Fig 4 a and b), the full effect remaining for about five minutes. In two experiments papaverine in large doses before trauma resulted



Fig 6 a) Normal angiogram of the left femoral artery b) Angiogram after local application of 0.08 mg epinephrine in 20 ml saline. Marked spasm



Fig 7 a) Angiogram of the left femoral artery after direct trauma to the artery. Moderate spasm b) Angiogram one minute after direct application of Carbocain 1%. Good but not complete relief of spasm



Fig 11 a) Angiogram of the left femoral artery after slight trauma to the femoral nerve. Slight spasm. b) Angiogram one minute after injection of 0.125 mg. Duvadilan through the catheter. The femoral artery is much wider than in the control.

in only slight spasm after the injury. Lledorsin (Sandoz, Switzerland) has been investigated three times in a dose of 0.0035 mg, only slight effect was produced. Narcosis with ether on an open mask at different depths of anaesthesia was tried without effect to relieve spasm. Rhinomacrodex given through the catheter in a dose of 10 ml affected vasoconstriction only slightly.

Treatment of spasm of the carotid artery. This has been undertaken on nine occasions. Spasm of the common carotid artery, which was usually slight, was relieved by infiltration with local anaesthesia. Dibenyline and Regitin hardly affected the spasm. Duvadilan intraarterially had some effect although this was not so obvious as in other vascular areas. Inderal had no effect at all. Spasm of the internal carotid artery, which is a small vessel in the rabbit, could be relieved only by local anaesthesia.

Discussion

Vasomotion has been extensively studied by many physiologists (see for example Handbook of Physiology, Circulation). The reactions of blood vessels to such stimuli as ion environment, vaso-active drugs and electrical stimulation have been closely investigated. Less thorough studies of more unspecific stimuli, such as trauma to arteries and nerves, have been performed. Both clinically and experimentally it has been demonstrated that trauma may cause spasm, but the mechanism is not clear. Direct mechanical stimulation of the vessel wall may produce spasm and KIMMOTH (1952) ruled out nervous stimuli as the cause.

TODD (1913) and TELFORD & STOPPORD (1930) pointed out that compression of the brachial plexus may produce the vascular symptoms in the syndrome of cervical rib, whereas LEWIS & PICKERING (1934) considered the vessel changes in such cases to be purely of a mechanical nature. KŁOWSKI (1955) successfully treated one case of spasm of the brachial artery after trauma by injection of local anesthesia in the median nerve. SCHWARTZ et coll (1961) found in dogs that spasm provoked by trauma may vanish after injection of local anesthesia in the sheath of the supplying nerve. Furthermore it has been demonstrated by WARREN et coll (1942), DE JONG (1961) and BERGSTRAND (1965) that vasodilatation of the arteries of the arm is obtained after infiltration of local anesthesia in and around the brachial plexus. MORTON & SCOTT (1931) and COHEN (1941) described spinal anesthesia as a method for relief of arterial spasm in the human leg. For the same purpose sympathectomy was performed by FREEMAN (1949) in man, by BARNES & TRUETA (1942) in the rabbit, and by MARTIN et coll (1949) in the dog. Periarterial dissection in order to abolish spasm has been described by LANGLEY (1923) in the cat, and by MONTGOMERY & IRELAND (1935), GRIFFITHS (1940) and COHEN (1941, 1944) in man.

It is obvious that traumatic arterial spasm can be caused by different mechanisms. Direct stimulation of the smooth muscles of the vessels or of the vasomotor nerves is one cause. Another cause is indirect stimulation transmitted via the sensory nerves in the neighbourhood of the vessel. The liability to spasm is influenced by psychogenic factors via the vasomotor center (MARINO et coll 1965).

The internal, external and common carotid arteries are surrounded by nerve fibres from the superior cervical ganglion. The axillary and brachial arteries are supplied and surrounded by sympathetic fibres from the brachial plexus (DE JONG 1961). The innervation of the hind limb vessels of the cat has been investigated by MOORE & MOORE (1933), and of the dog by CLOVINGER & GREEN (1955) and ZIMMERMAN (1966). CLOVINGER & GREEN found by electrical stimulation of nerves that 89.1% of the vasculature of the hind limb vessels was innervated by the sciatic nerve, 2.9% by the femoral nerve and 2.1% by fibres around the femoral artery.

The marked spasm that trauma causes in the brachial artery may depend on the close relationship between the artery and the nerves. KINSMOTH et coll (1949) stated that in cats and rabbits traumatic spasm is easily provoked in the brachial and femoral arteries, with slight difficulty in the common and external iliac arteries and with great difficulty in the abdominal aorta and the common carotid artery. WICKBOM & BARTLEY (1957) and LINDBOM (1957) produced spasm in human subjects on puncture or catheterization with angiography.

especially in medium-sized arteries such as the brachial artery or the deep femoral artery. We found that trauma caused spasm more readily in the brachial and internal carotid arteries than in the femoral artery and that it was difficult to provoke this effect in the common carotid artery. The experiments thus confirm the findings of WICKBOM & BARTLEY (1957) and LINDBOM (1957) that the spasm liability diminishes with increasing diameter of the vessel. This might to some extent depend upon the fact that the proportion of elastic tissue of the wall increases with the diameter of the vessel. According to LINDBOM (1957) fibrosis of the medial layer of the arterial wall is common in the middle-aged and elderly. Arteries so affected cannot contract and spasm is therefore uncommon in these types of patients; according to LINDGREN (1969) this indicates the importance of age. The age factor was not investigated in the present work.

Trauma of the femoral nerve caused less spasm than direct arterial trauma and can be explained by the observation by CLOWNINGER & GREEN (1955) that most of the innervation of the vessels of the hind limb is transmitted by the sciatic nerve. The sensory innervation of the arteries has been investigated by e.g. MOORE & MOORE (1933) and MOORE & SINGLTON (1933). Spasm is common especially in young individuals in clinical work with puncture and catheterization. It seems most often to be caused by stimulation of the inside of the vessel wall by the tip of the needle or the catheter or by the jet of contrast medium.

The smooth musculature of the vessel wall contracts slowly with small amounts of energy, the contraction being maintained at a low level of energy consumption. Relaxation occurs gradually as evident after death, when the arteries may stay constricted for a long time. Spasm is also maintained *in vivo* for a long time if active therapy is withheld.

The investigation indicates that to prevent or abolish spasm it is necessary to apply local anesthesia freely around the artery and the surrounding nerves and that it should also be infiltrated centrally to the puncture. The spasm has a tendency to spread both centrally and peripherally. It is always better to apply anesthesia before trauma than after. The severe cases of spasm that arise in clinical angiography have appeared after local anesthesia limited to the skin. The disadvantages of a large amount of anesthetic is, of course, that it may make arterial pulsation difficult to palpate, but this can be overcome by adding Hyalas (Hyaluronidase, Leo, Sweden), 40 IU to 10 ml of anesthetic, or by massaging the infiltrated area. In earlier clinical descriptions of spasm in connection with puncture local anesthesia has not been mentioned.

The liability to spasm is increased in tense and nervous individuals. MARINO *et coll.* (1965) demonstrated experimentally that psychostress potentiated

vasoconstriction on injection of epinephrine or ergotamine. Some kind of sedation before the catheterization is thus important.

Established spasm has been treated by periarterial dissection, sympathetic block, sympathectomy, local anesthesia to the supplying nerve and various vasoactive drugs given locally or intraarterially. Papaverine has been tried with varying results by GRIFFITHS (1940), FREEMAN (1949), MARTIN *et coll* (1949), RADNER (1951), KINMONTH (1952), SUTTON (1952) and SCHWARTZ *et coll* (1961). Infiltration of procaine has been stated to relieve arterial spasm by KINMONTH (1952), KULOWSKI (1955) and SCHWARTZ *et coll* (1961). Good results with Priscol have been reported by KINMONTH (1952) and WICKBOM & BARTLEY (1957).

Of the drugs tested by the present authors the β receptor stimulating agent Duvadilan was the best. It relieved spasm of the brachial and femoral arteries effectively in a low intraarterial dose that produced little effect on the general circulation. Duvadilan gave complete relief of spasm after 30 seconds, the vessels usually being wider. Slight spasm sometimes returned after more than ten minutes. A good effect was obtained with the α receptor blocking agents Regitin and Dibenzylne as occurred with papaverine, a good effect in high doses although its traditional role as a spasm relieving drug seems to be outdated. The ganglion blocking agents had no effect on the calibre of the vessels, perhaps explained by the drop in blood pressure that occurs on their administration. Eleodisin, Rheo-macrodex and ether narcosis exerted only small positive effects.

Conclusions

Prevention of spasm at puncture and catheterization is important. The patient should be calmed with sedation and a good local anesthetic given before the procedure. If spasm appears one of the new local anesthetics should be applied, if necessary as conductance anesthesia, e.g. plexal anesthesia. Failing relief, a vasodilating drug should be injected intraarterially, preferably Duvadilan, if this drug is not accessible, an α receptor blocking agent or papaverine should be tried.

SUMMARY

Arterial spasm caused by trauma to an artery or adjacent nerve has been studied experimentally in rabbits. Severe spasm was easily provoked in the brachial artery, the femoral artery responded less and the common carotid artery was resistant. The treatment of spasm is discussed.

especially in medium-sized arteries such as the brachial artery or the deep femoral artery. We found that trauma caused spasm more readily in the brachial and internal carotid arteries than in the femoral artery and that it was difficult to provoke this effect in the common carotid artery. The experiments thus confirm the findings of WICAROM & BARTLEY (1957) and LINDBOM (1957) that the spasm liability diminishes with increasing diameter of the vessel. This might to some extent depend upon the fact that the proportion of elastic tissue of the wall increases with the diameter of the vessel. According to LINDBOM (1957) fibrosis of the medial layer of the arterial wall is common in the middle-aged and elderly. Arteries so affected cannot contract and spasm is therefore uncommon in these types of patients, according to LINDGREN (1969) this indicates the importance of age. The age factor was not investigated in the present work.

Trauma of the femoral nerve caused less spasm than direct arterial trauma and can be explained by the observation by CLOWNINGER & GREEN (1955) that most of the innervation of the vessels of the hind limb is transmitted by the sciatic nerve. The sensory innervation of the arteries has been investigated by e.g. MOORE & MOORE (1933) and MOORE & SINGLETON (1933). Spasm is common especially in young individuals in clinical work with puncture and catheterization. It seems most often to be caused by stimulation of the inside of the vessel wall by the tip of the needle or the catheter or by the jet of contrast medium.

The smooth musculature of the vessel wall contracts slowly with small amounts of energy, the contraction being maintained at a low level of energy consumption. Relaxation occurs gradually as evident after death, when the arteries may stay constricted for a long time. Spasm is also maintained in vivo for a long time if active therapy is withheld.

The investigation indicates that to prevent or abolish spasm it is necessary to apply local anaesthesia freely around the artery and the surrounding nerves and that it should also be infiltrated centrally to the puncture. The spasm has a tendency to spread both centrally and peripherally. It is always better to apply anaesthesia before trauma than after. The severe cases of spasm that arise in clinical angiography have appeared after local anaesthesia limited to the skin. The disadvantages of a large amount of anaesthetic is, of course, that it may make arterial pulsation difficult to palpate, but this can be overcome by adding Hyalas (Hyaluronidase, Leo, Sweden), 40 IU to 10 ml of anaesthetic, or by massaging the infiltrated area. In earlier clinical descriptions of spasm in connection with puncture local anaesthesia has not been mentioned.

The liability to spasm is increased in tense and nervous individuals. MARINO et coll. (1965) demonstrated experimentally that psycho-stress potentiated

- GRIFFITHS D L Volkmann's ischaemic contracture *Brit J Surg* 28 (1940—1941), 239
- KINMONTH J H The physiology and relief of traumatic arterial spasm *Brit med J* 1 (1952), 59
- SIMEONE F A and PERLOW V Factors affecting the diameter of large arteries with particular reference to the effect of vasomotor drugs *Am J Physiol* 104 (1933), 459
- KOHLER R Regular alternating changes in arterial width in lower limb angiograms *Acta radiol Diagnosis* 3 (1965), 529
- KROH F Frische Schusserletzungen des Gefassapparatus Eine klinisch-experimentelle Studie *Bruno Beitr klin Chir* 108 (1917), 111
- KULOWSKI J Segmental arterial spasm of the brachial artery *Surgery* 38 (1955), 1087
- VON KUTTNER H und BARLICH M Beitrage zur Chirurgie der grossen Blutgefassstamme IV Der traumatisch segmentare Gefasskrampf *Bruno Beitr klin Chir* 120 (1920), 1
- KYLÖNEN K E J Traumatic arterial lesions *Acta chir scand Suppl* 357 (1956), 277
- LANGLEY J N The vascular dilation caused by the sympathetic and the course of vasomotor nerves *J Physiol* 58 (1923—1924), 70
- LERICHER R Surgery of pain *Baillière, Tindall, & Cot* London 1939
- and FONTAINE R Experimental and clinical contribution to the question of the innervation of the vessels *Surg Gynec Obstet* 47 (1928), 631
- LEVIN H S, MEISSER J V and PINES J Repeated venous and arterial catheterization in man *Amer Heart J* 73 (1967), 475
- LEWIS T and PICKERING G W Observations upon maladies in which the blood supply in digits ceases intermittently or permanently and upon bilateral gangrene of digits, observations relevant to so-called 'Raynaud's disease' *Clin Sci* 1 (1934), 327
- LINDSOM A Arterial spasm caused by puncture and catheterization an arteriographic study of patients not suffering from arterial disease *Acta radiol* 47 (1957), 449
- LINDGREN E Personal communication (1969)
- LINDGREN P, NORDENSTROM B and TORSELL G Arterial spasm treated with sodium acetate *Acta chir scand* (1959) Suppl No 245, p 301
- LISI P M, DUNCAN K W and PETERS E L A survey of the effects of isosuprine on non-vascular smooth muscle *J Pharmacol exp Ther* 129 (1960), 191
- MAKINS G H Gunshot wounds in the blood vessels, official medical history of the war *Surgery* 2 (1919), 175 and 180
- MARINO A, MAZZEO F, DI MEZZA E and BRACALE G Arteropatia periferica da adrenalina + ergotamina + psicostress nella cavia (In Italian) *Arch int Pharmacodyn* 156 (1965), 455
- MARTIN W B, LAUFMAN H and TLELL S W Rationale of therapy in acute vascular occlusions based upon micrometric observations *Ann Surg* 129 (1949), 476
- MONTGOMERY A H and IRELAND J Traumatic segmentary arterial spasm *J Amer med Ass* 105 (1935), 1741
- MOORE R M and MOORE R E Studies on the pain sensibility of arteries I Some observations on the pain sensibility of arteries *Amer J Phys* 104 (1933), 259
- and SINGLETON A O Studies on the pain sensibility of arteries II Some observations on the pain sensibility of arteries *Amer J Phys* 104 (1933), 276
- WILLIAMS J H and SINGLETON A O Vasoconstrictor fibres Peripheral course as revealed by a roentgenographic method *Arch Surg* 26 (1933), 320
- MORTON J J and SCOTT M W J The differentiation of peripheral arterial spasm and occlusion in ambulatory patients *J Amer med Ass* 97 (1931), 1212

ZUSAMMENFASSUNG

Experimente wurden an Kaninchen vorgenommen um die Entstehung von arteriellen Spasmen zu studieren die durch Trauma der naheliegenden Gefasse oder Nerven hervorgerufen wurden. Schwerartige Spasmen konnten ohne Schwierigkeit in der Brachialarterie hervorgerufen werden. Die Femoralarterie reagierte weniger und die Carotisarterie blieb unbeeinflusst. Die Behandlungswege der Spasmen werden diskutiert.

RÉSUMÉ

Les auteurs ont étudiés expérimentalement sur des lapins le spasme artériel cause par un traumatisme portant sur une artère ou sur les nerfs voisins. On provoque aisément un spasme grave sur l'artère humérale. L'artère femorale répond moins et l'artère carotide primitive ne répond pas au traumatisme. Les auteurs examinent le traitement du spasme.

REFERENCES

- ADAMS D F, OLIN J and REDMAN H. Catheterization of arteries in the rabbit. *Radiology* 84 (1965) 531.
- BARNES J M and TRULETA J. Arterial spasm: an experimental study. *Brit J Surg* 30 (1942-1943) 74.
- BERGSTRAND I. Tekniken vid handangiografi (In Swedish). *Nord Med* 73 (1965) 375.
- CLARK C W. Traumatic arterial spasm. *Brit med J* 2 (1943) 167.
- CLONNINGER G L and GREEN H D. Pathways taken by the sympathetic vasomotor nerves from the sympathetic chain to the vasculature of the hind leg muscles of the dog. *Amer J Physiol* 181 (1955) 258.
- COHEN S M. Traumatic arterial spasm. *Guy's Hosp Rep* 90 (1941) 201.
- Traumatic arterial spasm. *Lancet* 1944 I p 1.
- CONSOLE A D. Segmental arterial spasm associated with supracondylar fracture of the elbow. Report of a case. *Surg Clin N Amer* 28 (1948) 467.
- DEBAKEY M F and SIMEONE F A. Battle injuries of the arteries in world war II. *Ann Surg* 123 (1946) 534.
- DEJONG R H. Axillary block of the brachial plexus. *Anesthesiology* 22 (1961) 215.
- ELFVIN P. Angiography of the internal carotid with use of the catheter technique. *Radiology* 75 (1960) 80.
- (THE) ERGOL ALKALOIDS. CHEMISTRY, PHARMACOLOGY AND CLINICAL APPLICATION. Sandoz Ltd Basel.
- FREEMAN N E. Acute arterial injuries. *J Amer med Ass* 139 (1949) 1125.
- GARROW E and KUSHNICK T. Management of femoral artery obstruction. *Amer J Dis Child* 110 (1965) 570.
- GESENIUS H. Über den Spasmus grosserer Arterien. *Berl med Z* 1 (1950) 302.
- GRANT R T. Observations on local arterial reactions in the rabbits ear. *Heart* 15 (1929-1931) 257.
- GRIFFIN P P, GREEN H D, YOUNG P L and JOHNSON H D. Effects of acute and chronic denervation of the hind leg of the dog on the blood flow response in the vascular beds of skin and muscle to adrenergic drugs, and to adrenergic blockade. *J Pharmacol exp Ther* 10 (1954) 93.

POSITION OF THE 'VENOUS ANGLE' IN THE MEDIAN SAGITTAL PLANE

A new topometric method

by

FRANZ P. PROBST

The deep veins of the brain, particularly the internal cerebral vein and its tributaries, can supply valuable information about adjacent cerebral structures. They are thus an important aid in the diagnosis of expanding intracranial lesions as well as in the investigation of malformations and other pathologic conditions of the brain substance.

The so-called 'venous angle' has been given much attention in the literature. The term 'venous angle' is not altogether correct, but it is used by some investigators to designate the angle formed between the striothalamic and internal cerebral veins. This angle may be distinguished more or less readily in lateral views, it appears in about 80 % of all carotid angiographies, and its apex marks the posterior superior limit of the interventricular foramen.

The position of the internal cerebral vein may be assessed without difficulty in the a p projection. It is harder to localize the venous angle in the sagittal plane because consideration must be paid not only to physiologic range in relation to

Submitted for publication 1 April 1969

- — Some angiospastic syndromes in the extremities *Ann Surg* 94 (1931), 839
- MUSTARD W T and BULL C Reliable method for relief of traumatic vascular spasm *Ann Surg* 155 (1962), 339
- and SIMMONS E H Experimental arterial spasm in the lower extremities produced by traction *J Bone Jt Surg* 35 B (1953), 437
- NARSETH D C and JONES J E Gangrene of the lower extremities of infants after femoral vein puncture *New Engl J Med* 268 (1963), 1003
- NEUMANN C, FOSTER JR A D and ROVENSTINE E A The importance of compensating vasoconstriction in unanesthetized areas in the maintenance of blood pressure during spinal anesthesia *J clin Invest* 24 (1945), 345
- PHYSIOLOGY (HANDBOOK OF) Section 2 Circulation Volume I—III American Physiological Society, Washington D C 1962
- RADNER S Vertebral angiography by catheterization A new method employed in 221 cases *Acta radiol* (1951) Suppl No 87
- ROSSMANN P and VAIRA I Histology of vasoconstriction and vasodilatation of muscular arteries by the freeze-drying method *Cor Vasa* 1 (1967), 77
- SCÉBAT L A study of the haemodynamic effect of a new vasodilator drug *CAA* 40 *Presse méd* 69 (1961), 338
- SCHIEGHTER M M Percutaneous carotid catheterization *Acta radiol Diagnosis* 1 (1963), 417
- SCHWARTZ S I, HARRIS P D and MAHONEY E B Polarographic evaluation of the reflex vasospasm produced by arterial injury and operations *Surgery* 49 (1961) 36
- SHELDON P Percutaneous cannulation of the carotid artery *Brit J Radiol* 37 (1964), 526
- SUTTON M Arterial spasm due to an intravenous infusion *Brit med J* 2 (1952), 859
- TELFORD E D and STOPPFORD J S The vascular complications of cervical rib *Brit J Surg* 18 (1930), 557
- TODD T W The arterial lesion in cases of cervical rib *J anat Physiol (Lond)* 47 (1913), 250
- WARREN J V, WALTER C W, ROMANO J and STEAD JR E A Blood flow in the hand and forearm after paravertebral block of the sympathetic ganglia Evidence against sympathetic vasodilator nerves in the extremities of man *J clin Invest* 21 (1942) 665
- WHOLEY M H and BOCHER J Angiography in musculoskeletal trauma *Surg Gynec Obstet* 125 (1967), 730
- WICKBOW J and BARTLEY O Arterial 'spasm' in peripheral arteriography using the catheter method *Acta radiol* 47 (1957), 433
- WOLFF C-H The treatment of premature labour with Duvadilan *Geburtsh u Frauenheil* 27 (1967), 402
- ZIEGLER W Untersuchungen über die Gefäßwirkung eines neuen Sympathikolyticums Präparat 7337 — Ciba — 'Regitin' Dissertation, Bern 1954
- ZIMMERMAN B G Separation of response of arteries and veins to sympathetic stimulation *Circulat Res* 18 (1966) 429

POSITION OF THE 'VENOUS ANGLE' IN THE MEDIAN SAGITTAL PLANE

A new topometric method

by

FRANZ P. PROBST

The deep veins of the brain, particularly the internal cerebral vein and its tributaries, can supply valuable information about adjacent cerebral structures. They are thus an important aid in the diagnosis of expanding intracranial lesions as well as in the investigation of malformations and other pathologic conditions of the brain substance.

The so-called 'venous angle' has been given much attention in the literature. The α -

tor
ven
ap.
about 60° of all carotid angiographies, and its apex marks the posterior superior limit of the interventricular foramen.

The position of the internal cerebral vein may be assessed without difficulty in the a.p. projection. It is harder to localize the venous angle in the sagittal plane because consideration must be paid not only to physiologic range in relation to

Submitted for publication 1 April 1969

- — Some angiospastic syndromes in the extremities *Ann Surg* 94 (1931), 839
- MUSTARD W T and BULL C Reliable method for relief of traumatic vascular spasm *Ann Surg* 155 (1962), 339
- and SIMMONS E H Experimental arterial spasm in the lower extremities produced by traction *J Bone Jt Surg* 35 B (1953), 437
- NANSETH D C and JONES J E Gangrene of the lower extremities of infants after femoral vein puncture *New Engl J Med* 268 (1963), 1003
- NEUMANN C, FOSTER JR A D and ROVENSTINE E A The importance of compensating vasoconstriction in unanesthetized areas in the maintenance of blood pressure during spinal anesthesia *J clin Invest* 24 (1945), 345
- PHYSIOLOGY (HANDBOOK OF) Section 2 Circulation Volume I—III American Physiological Society, Washington D C 1962
- RADNER S Vertebral angiography by catheterization A new method employed in 221 cases *Acta radiol* (1951) Suppl No 87
- ROSSMANN P and VAVRA I Histology of vasoconstriction and vasodilatation of muscular arteries by the freeze-drying method *Cor Vasa* 1 (1967), 77
- SCFBAT L A study of the haemodynamic effect of a new vasodilator drug, CAA 40 *Presse méd* 69 (1961), 338
- SCHIECHTER M M Percutaneous carotid catheterization *Acta radiol Diagnosis* 1 (1963), 417
- SCHWARTZ S I, HARRIS P D and MAHONEY E II Polarographic evaluation of the reflex vasospasm produced by arterial injury and operations *Surgery* 49 (1961), 36
- SHELDON P Percutaneous cannulation of the carotid artery *Brit J Radiol* 37 (1964), 526
- SUTTON M Arterial spasm due to an intravenous infusion *Brit med J* 2 (1952), 859
- TELFORD E D and STOPPFORD J S The vascular complications of cervical rib *Brit J Surg* 18 (1930), 557
- TODD T W The arterial lesion in cases of cervical rib *J anat Physiol (Lond)* 47 (1913) 250
- WARREN J V, WALTER C W, ROMANO J and STEAD JR E A Blood flow in the hand and forearm after paravertebral block of the sympathetic ganglia Evidence against sympathetic vasodilator nerves in the extremities of man *J clin Invest* 21 (1942) 665
- WHOLEY M H and BOCHER J Angiography in musculoskeletal trauma *Surg Gynec Obstet* 125 (1967), 730
- WICKBOM I and BARTLEY O Arterial 'spasm' in peripheral arteriography using the catheter method *Acta radiol* 47 (1957), 433
- WOLFF C-H The treatment of premature labour with Duvadilan *Geburtsh u Frauenheil* 27 (1967), 402
- ZIEGLER W Untersuchungen über die Gefäßwirkung eines neuen Sympathikolyticums Präparat 7337 — Ciba — 'Regitin' Dissertation Bern 1954
- ZIMMERMAN H G Separation of response of arteries and veins to sympathetic stimulation *Circulat Res* 18 (1966), 429

media and posterior horn, these veins run in the medial wall of the lateral ventricle and enter the internal cerebral vein at slightly different angles

2 A lateral group including veins from the lateral wall of the cella media, these are located subependymally on the medial surface of the caudate nucleus, and when they do not empty into the striothalamic vein, run medially on the superior surface of the thalamus. They then pass beneath the stria terminalis and the taenia choroidea, enter the velum interpositum, and finally reach the internal cerebral vein

Orientation of the venous angle by objective measurement requires that the apex of the angle lies in the foramen of Monro, it is also important to know whether a 'false venous angle' is present, in other words whether the striothalamic vein enters the internal cerebral vein behind the foramen

False venous angles All variations with 'medial' or 'lateral' vein stems opening into the anterior third of the internal cerebral vein may cause diagnostic difficulties. They may erroneously suggest a displacement of the venous angle, with elevation or distortion of the internal cerebral vein if the true venous curve running through the foramen of Monro is not visible in the phlebogram. Invisibility of the true angle may be due to aplasia, hypoplasia, or inadequate contrast filling. The venous angle may in some cases be visible only for a brief moment, and may sometimes be seen only in one view in the early venous phase. The true conditions may then be ascertained by studying each film in the sequence-set with a subtraction mask. Not infrequently, identification of the venous angle is made difficult by overlying superficial or the vein of Labbe. However, as these vessels more rapidly than through the deep veins views from the late venous

(1956) and

= (1955) facilitate the recognition of false venous angles

Orientation of the venous angle by objective measurement All methods for localization of the venous angle in the sagittal plane by measurements are based upon its position being related to certain craniometric points. These points should meet certain requirements. They should lie in the median sagittal plane, be exact and always capable of definition, and be situated in regions having the least possible variability. The foot points most commonly used for earlier coordinate systems were the tuberculum sellae, nasion or a point on the glabella, bregma, lambda,inion, opisthion, or basion. Even points such as 'the lowest point in the sella turcica', 'the top of the dorsum sellae', and 'the point where the internal cerebral vein enters the straight sinus' have been used. Structures with a lateral

cranial shape and size but also to the relatively high rate of anomalies in the anterior portion of the internal cerebral vein and its tributaries

Many attempts have been made to find a more exact method than visual assessment for determining the position of the venous angle in the sagittal plane. The technique for orientation of the pineal body described by VASTINE & KINNEY (1927) has been used as a prototype in some of these investigations. Other authors have tried various coordinate systems in which the lines of reference were determined by given craniometric points. As with the pineal body, the multitude of methods suggested for measurement of the venous angle are indications that they are not wholly satisfactory.

Anatomy. Excellent descriptions of the deep-vein system of the brain have been published by, among others, JOHANSSON (1954), MOROHISAKI et coll (1956), RING (1959), and WOLF & HUANG (1964).

The striothalamic vein is usually the largest tributary to the internal cerebral vein. It forms the continuation of the terminal vein which lies in the terminal groove between the thalamus and the caudate nucleus. After being joined by an anterior and a posterior caudate vein, it curves medially around the anterior part of the thalamus in the direction of the foramen of Monro.

The aperture between the lateral and third ventricles consists of a short, crescent-shaped canal, the foramen of Monro, across the upper margin of which the striothalamic vein together with the choroid plexus passes to join the vein of the septum pellucidum and the choroid vein to form the internal cerebral vein. This courses backwards as a continuation of the curve with its convexity forwards produced by the striothalamic vein. There is no break in the continuity of the curve, and thus, according to general opinion, the internal cerebral vein always arises in the foramen of Monro. The vein of the septum pellucidum sometimes terminates occipital to the origin of the internal cerebral vein. The latter vessel has a characteristic course, running backwards in the roof of the third ventricle and along the medial border of the thalamus. Viewed laterally, it describes a sinus-shaped curve with its convexity upwards. It lies mainly in a parasagittal plane close to the midline. The two internal cerebral veins commonly unite above the suprapineal recess to receive the basal veins and form the great vein of Galen, which follows the splenium of the corpus callosum and joins with the inferior sagittal sinus to continue as the straight sinus.

A number of tributaries, most of them minute and not demonstrable at clinical angiography, empty into the internal cerebral vein. Only a few of the larger stems are of interest, and according to WOLF & HUANG (1964) may be classified in two main groups:

1. A medial group including veins from the roof and medial wall of the cella



Fig 2 Method of LIN et al¹
(1955)

planum sphenoidale, and the anterior vertical axis was drawn tangent to the inner table of the frontal bone. The internal cerebral vein in normal cases lay in the third and fourth squares, counting from the front, and in the second row of squares, counting from the base line. As both of these methods gave only approximate orientation they will not be discussed.

MASPES & DONEGANI (1952) attempted to determine the normal variations of the venous angle with a rectangular coordinate system (Fig 1a). The base line $N-I$ consisted of a line joining the point on the anterior wall of the frontal sinus lying above the nasion and farthest rostrally (i.e. not a point on the nasion), and the tip of theinion. The X axis was drawn in $NI/2 \approx O$. The distance $O'-M$ (M = the venous angle) was placed in relation to $O-V$ and the distance $O'-I$ in relation to $N-I$ (22 to 36% and 52 to 60%, respectively), a rectangular zone of dispersion 15 mm long and 14.7 mm high was obtained. In the light of what has been stated regarding the suitability of different craniometric orientation points as a basis for a coordinate system, the base line chosen by these investigators must be regarded as unsuitable, their results confirm this opinion. The nearly square topogram permits diagonal variations of, at the most, 22 mm in the position of the angle. A non-elliptic topogram is unsuitable, and cannot reflect the normal range of variation correctly.

MASPES & DONEGANI also described a goniometric system of measurement in which, however, the points for the angle were unfavorably located in regions of great variability. The resulting topogram had an irregular, trapezoid form, and furthermore varied in shape and size from case to case.

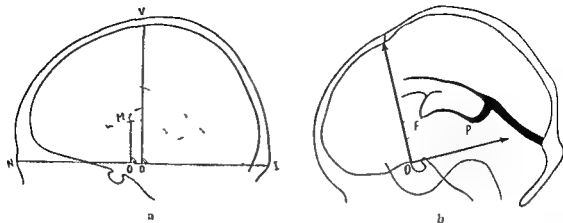


Fig 1 a) Method of MASPER & DONECARI (1952) b) Method of JOHANSSON (1954)

site, such as the roof of the orbit or the external auditory meatus, have also been employed

BERGERHOFF's (1953) investigations have demonstrated that the cranium develops around the tuberculum sellae. The part of the skull situated in front of the tuberculum sellae and the bregma is considered to be subject to relatively little variation, while points in the parietal or occipital part lie in regions of greater variability. Judged by these criteria, the various craniometric points differ widely in suitability. The site of the tuberculum sellae can nearly always be determined and is considered to be the point that varies least, it lies close to the venous angle. This point thus seems to be the most suitable one to use as the foot point for the base line of the coordinate system. If a system with rectangular coordinates is used, one more craniometric point, theasion for instance, will be sufficient to give the base line a direction. If a coordinate system whose lines of reference are determined by four craniometric points is selected, it will of course not be rectangular but will vary from case to case, and this reduces the possibility of defining the normal range of variation for the venous angle. The physiologic variation of the craniometric measurement points affects to a greater or less degree the position of the venous angles in relation to the origin of the system.

Earlier methods The first authors to attempt systematic localization of the venous angle were CURRY & CULBRETH (1951), who measured the distance from the 'anterior convexity' of the striothalamic vein to the extremity of the posterior clinoid process and found that it ranged from 3.5 to 4 cm.

UMBACH (1952) used a rectangular coordinate system consisting of a squared net with 3 cm \times 3 cm meshes. The base line was placed parallel to and in the

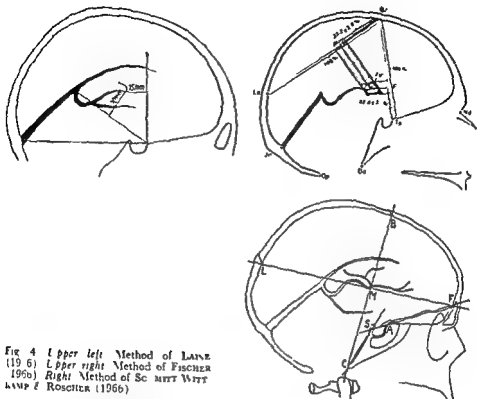


Fig. 4 Upper left Method of LAINE (1966) Upper right Method of FISCHER (1966b) Right Method of SCHEIT WITT (1966)

direction it was 12 mm in 92 % of the cases and 18 mm for all cases, and in the basocranial direction 12 mm in 98.7 % and 14 mm in 100 % of the cases. In 55 % of the authors' 26 cases with space-occupying lesions (including 3 cases of hydrocephalus), the venous angle fell outside the narrower limiting range, but only 37 % exceeded the wider limits. These investigators concluded that their method had only a restricted application. The method takes into account the size and configuration of the skull by relating the two lines of reference with total length and height, but its weaknesses are fairly obvious. It is a coordinate system with varying angulation, since the angles at the O point (A) vary from case to case. The venous angles are determined only in two major directions (which vary furthermore), and consequently the two resulting charts cannot be integrated into a topogram allowing localization of the individual venous angles with respect to distance and direction in relation to a calculated O point. The latter measure is possible only in topograms based on an unvarying coordinate system.

WOLF, NEWMAN & SCHLESINGER (1955), using a template, worked out a

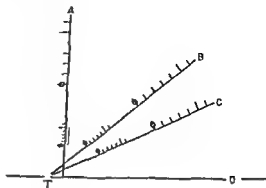


Fig 3 Method of WOLI, NEWMAN & SCHLESINGER (1955) 'Constant ratio scale' A for determining position of venous angle

JOHANSSON (1954) used a rectangular coordinate system (Fig 1b) with the origin in the tuberculum sellae (O). The distance from O to the endobregma formed the Y-axis, and the X-axis was drawn at right angles to this line, through the origin. JOHANSSON determined the coordinates for point Γ (the venous angle) in 200 normal angiograms, and found that 80 % of the observations lay within a circle with a diameter of 15 mm. Calculated with ± 3 sigma, the outer limit for the normal variations formed a circle with a diameter of 22 mm. Only 15.5 % of this author's patients with expanding cerebral lesions had values outside the 3-sigma limit. He concluded that displacement of the venous angle could be demonstrated by his technique with certainty in relatively few cases. He also considered that visual inspection by an experienced examiner was a better method for determining the shape and position of the venous angle than his measuring technique. JOHANSSON's results were carefully described and analyzed statistically, but nevertheless they must have been influenced considerably by the variability of the bregma. Every variant of the bregma causes rotation of the coordinate system and distorts the distribution and natural variation range of the venous angle.

LIN et coll (1955) and MOKROUSKA et coll (1956) employed a measuring technique similar to VASTINE & KINER's (1927) method for orientation of the pincal body (Fig 2). Their investigation was based on 100 'normal' cases and the position of the venous angle could be established in 77 instances. The base line (B) was drawn through the tuberculum sellae, its direction being determined by the nasion. A perpendicular line, the Y axis, was drawn from this, through the convexity point along the venous angle (A) to the inner table of the vault. The position of the venous angle in the anteroposterior direction was measured along a line passing through A, which had to be the longest fronto-occipital distance between the inner tables (D). The two orientation charts presented were obtained by diagrammatically plotting D against D' and C against C'. For each diagram the range of variation was limited empirically by parallel lines, in the anteroposterior

scales, B and C, will not be discussed, as these are outside the scope of this review

LARNE et coll (1956) worked out a triangular topogram based on 69 normal phlebograms. Their base line was drawn from the tuberculum sellae to the lower margin of the sulcus for the transverse sinus. The Y axis was drawn perpendicular to this line, in the tuberculum sellae, and the X axis ran between the tuberculum and the junction of the vena magna with the inferior sagittal sinus (Fig. 4). Thus, the direction of the X axis was determined by a point which probably is the most variable of all so-called 'fixed points'. A triangular topogram constructed from such varying coordinates obviously cannot reproduce the physiologic variations of an anatomic structure. This method nevertheless became known and was relatively well accepted.

RING (1959) tested LARNE's method and found that only 55 % of the venous angles lay in the triangular topogram. He tried to improve the technique by eliminating the ampulla Galeni as a point of direction for the X-axis, using instead the point where the posterior pericallosal vein joins the vena magna. This point has a more constant position, but on the other hand it is not always visible (not seen in about 50 % of cases). He worked out an elliptic topogram, in which 75 % of his venous angles could be included. The size of the ellipse was given as 6.8 mm, but the direction of the long axis was not mentioned. This ellipse is, of course, too small to include the normal range of the venous angle.

BRANDT (1959), in an extensive goniometric investigation, measured a large number of angles from the tuberculum sellae, bregma and ampulla Galeni to the venous angle. He found no statistical covariation between these points. He also measured the angles to the tuberculum sellae and a base line from the tuberculum tangent to the orbital roof; the distance to the tuberculum was measured as well. The positions of the venous angles were placed in an ellipse. For 90 % of the cases the ellipse had a long axis of 23 mm and a short axis of 19 mm. The magnification factor was 1.27, and reduced to absolute values the measurements of the ellipse were 18/14.8 mm. This method does not take the size and configuration of the skull into consideration, and the ellipse is far too large to be practically usable.

FISCHER, in 1966, presented another technique for orientation of the venous angle. By means of a system with coordinates of varying lengths, and with varying angulation, Br—Ts and Br—La, he determined the range of variation perpendicular to, and along these lines (Fig. 4), and obtained the following results. If the line between the tuberculum sellae and endobregma is divided from below in the ratio of 32.58 % \pm 3.07 %, and the line between the endobregma and endolambda is divided from above in the ratio of 33.32 % \pm 2.5 % and if perpendicular lines are drawn at these points, a parallelogram is obtained. The venous angle lies as a rule at the point of intersection of the central lines. The natural variation range

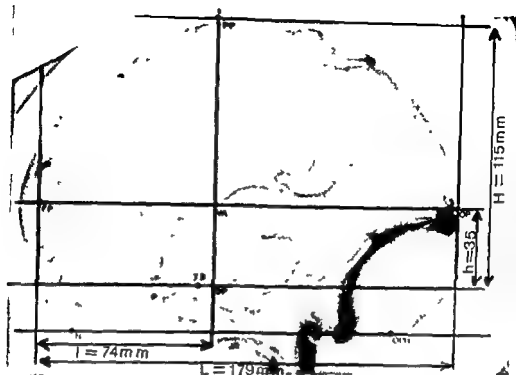


Fig 5 Author's method $\backslash \backslash$ — venous angle, TS — tuberculum sellae BP — foot point

proportionality system described as 'constant ratio scales' for determining the expected positions of the points AL (venous angle), MP and LP (Fig 3). Constant ratio scale A was drawn perpendicular to the base line (tuberculum sellae to lower margin of the sulcus for the transverse sinus), with the foot point located 13 mm occipital to the tuberculum sellae. The method was an attempt to establish a constant ratio between the variation range of the venous angle and the inner table of the calvarium in relation to the tuberculum sellae along the vertical line. The range for the venous angle along this line was given as 18 mm, the range in the frontal direction was not considered important, and no figures were mentioned. One of the venous angles investigated lay 2.5 mm behind the vertical line. Venous angles situated more than 2.5 mm behind constant ratio scale A were interpreted as displaced. The method is in principle a modification of the technique used by Lin et coll., and may be said to correspond to their orientation chart, which shows the variations in the basovertical direction. The main difference is that the coordinates are rectangular and that the method does not take into consideration the variations in the fronto-occipital direction. Twenty-four normal phlebograms were used as a basis for the method. The techniques recommended for determining points MP and LP by using two other constant ratio

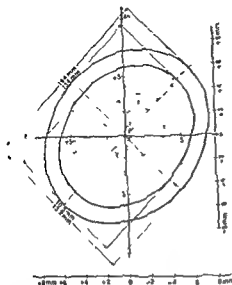


Fig 7 Prediction areas of venous angles calculated for 95 % and 99 % probability, measuring 110 mm² and 169 mm² respectively

by craniometric points such as the basion, bregma, lambda, and a point of intersection between the inner cortex of the frontal bone and a line from the tuberculum sellae making a tangent with the orbital roof. According to these authors, the venous angle usually lies at the intersecting point of the coordinates, and on the coordinates. The deviations from these lines decrease basoverically and fronto-occipitally, since the distribution in relation to each line follows the Gaussian distribution curve. The measurements were made on the principle that the distance to line L—F was determined parallel to line C—B, and vice versa. (The geometrical figure formed by coordinates and subcoordinates was a parallelogram. The distance between a venous angle and the point O was the long or the short diagonal, depending on whether it lay in the acute angled or the obtuse-angled segment of the coordinate system.) Each venous angle was then plotted in a system with rectangular coordinates, and the deviation values thus obtained were compiled into ellipses measuring 14/11.4 mm when calculated with $P=0.05$, and 17.4/11.4 mm when calculated with $P=0.01$ (magnification factor 1.3). The center of the ellipses lay 0.7 mm in front of the vertical coordinate and 0.4 mm above the horizontal coordinate. The long axis of the ellipse cut the abscissa at an angle of 20°, in other words, the ellipses sloped forward at the base. The area of the ellipse calculated with $P=0.01$ was 156 mm².

This technique seems better than all the earlier methods. The present author has however tried it in 30 consecutive carotid angiographies in which the bregma and lambda were visible, and found that the distances from the venous angle to

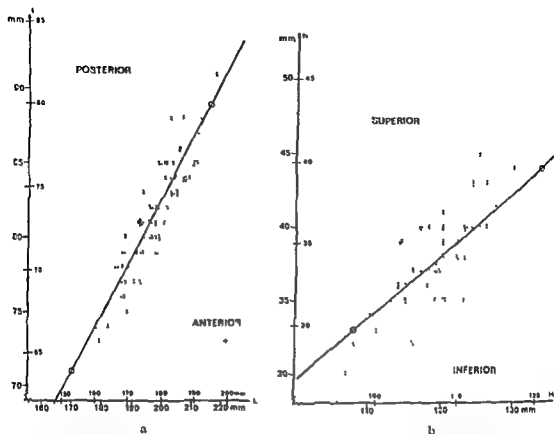


Fig. 6 Regression lines. Inner scales: absolute values; outer scales: magnification 1/11. a) Fronto-occipital range of venous angles in relation to inner length of skulls; b) Basovertical range of venous angles in relation to height of skulls.

(the 2-sigma value) will then be represented by an ellipsoid (as large as possible sketched empirically into the parallelogram). For geometrical reasons, the long axis of the ellipse can then never coincide with the long axis of the parallelogram. It may thus be said that the size, shape and direction of the ellipse varies from case to case, depending on the angle $La-Br-Ts$, and variations in the corresponding lines.

SCHMITT-WITTKAMP (1966), who also tried FISCHER's method, found that the mean area of the ellipse, when calculated with $P = 0.01$, was 2.7 cm^2 . As FISCHER's method is based on proportionality measurements, the range of variation will vary with the dimensions of the skull.

The latest contribution to the problem of localizing the venous angle was published by SCHMITT-WITTKAMP & ROSCHKE in 1966 (Fig. 4), who described an investigation based on 122 cases. These authors used a coordinate system with varying angulation, and the directions of the coordinates were determined

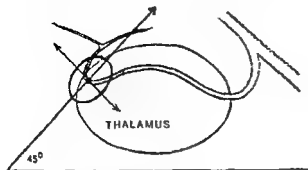


Fig 8 The ellipses slope toward the base line angle of inclination 45°

theless remarkably low in this material and the explanation probably lies in the program, with rapid film sequences, as well as in the systematical analysis of the views from the venous phase with the subtraction technique

Technique The system was regarded as lying in the median sagittal plane (Fig 5)

The line Na—OPH gives the direction for all lines in the system (the *direction line*)

The system is constructed on the *base line*, which is drawn parallel to the direction line, through the tuberculum sellae (TS)

The *venous angle horizontal* is drawn parallel to the former lines, through the venous angle (VA)

The *parietal line* is drawn parallel to the others, and tangentially to the inner table of the parietal bone

The following lines are drawn perpendicular to the base line

The *frontal line* which will be tangential to the inner table of the frontal bone, the *venous angle vertical* through VA, and the *occipital line*, which is made tangential to the inner table of the occipital bone

The following distances were measured in millimeters and half millimeters: FP—VA = frontal distance (1), FP—OP = total length (L), BP—VA = basal distance (h) and BP—PP = total height (H)

Two integrable charts were constructed from the length and height measurements by plotting (1) against (L) and (h) against (H). The range of the venous angles in a fronto-occipital direction in relation to skull length (chart I) and the range in vertical direction in relation to skull height (chart II) are shown in Fig 6. The regression line in each chart is identical with the y- and x axes, respectively in Fig 7, in which the charts are integrated. Each venous angle was plotted in relation to the coordinates y and x. The range of variation (prediction area) is limited by ellipses obtained by multivariate analysis. These were calcu-

the origin varied from 0 to 13 mm. The average distance was 5.66 mm, and in 9 cases the distance was greater than 7.5 mm. The original ellipse measurements (calculated with $P = 0.01$), when recalculated to allow for a magnification of 1.11, were 15 mm for the long axis and 9.8 mm for the short axis. Consequently, all distances exceeding 7.5 mm lay outside the ellipse, some of the other venous angles whose distances to the origin were greater than 4.9 mm also, of necessity, fall outside the ellipse.

The reason for this unsatisfactory result is to be sought in the previously mentioned wide individual variations in the bregma and lambda (BERGERHOFF), as well as in the inherent error of method. If values obtained in a coordinate system with varying angulation are transferred to a system with rectangular coordinates the relation to the origin will be altered for every venous angle, both as regards distance and direction, this will cause a radical change in the venous angle distribution, with consequences both for the dimensions and the angle of inclination of the ellipses.

If this geometrical error could be eliminated or reduced (which is not possible however, since 122 angle-varying coordinate systems cannot be integrated), the ellipses would probably be larger than mentioned, there would however still be no possibility of giving the ellipse an exact direction. Another unfavorable factor in this method is that the fixed points used are surprisingly often difficult to distinguish clearly.

Measurement method

Material. This was composed of 250 consecutive carotid angiographies from adults judged to be normal. The indications for the angiographic examinations had varied (epilepsy, vascular accident, and subdural hematoma or tumor).

At least two projections, half-axial and lateral, from each investigation were examined, and the views from the venous phase were studied with the subtraction technique. The criteria for selection were that the subependymal veins of the lateral ventricle should be sufficiently well filled with contrast medium to permit assessment of the shape and size of the ventricle, with the exception of the temporal horn, and that the venous angle and internal cerebral vein should be distinctly visible. Angiographies not fulfilling these conditions were discarded. Among the 250 cases, there were 31 (13.6%) with venous angles differing from the normal appearance and in sites typical of false venous angles. These cases were not used in the orientation measurements, 216 angiographies (86.4%) were thus available for the study of the normal range. False venous angles were present on one side only in 5 cases and the true position of the venous angle could be seen in the phlebogram from the other side. The frequency of false venous angles is never

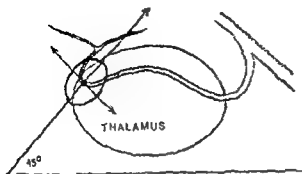


FIG 8 The ellipses slope to ward the base line angle of inclination 45°

theless remarkably low in this material and the explanation probably lies in the program, with rapid film sequences, as well as in the systematical analysis of the views from the venous phase with the subtraction technique

Technique The system was regarded as lying in the median sagittal plane (Fig 5)

The line Na—OPH gives the direction for all lines in the system (the *direction line*)

The system is constructed on the *base line*, which is drawn parallel to the direction line, through the tuberculum sellae (TS)

The *venous angle horizontal* is drawn parallel to the former lines, through the venous angle (VA)

The *parietal line* is drawn parallel to the others, and tangentially to the inner table of the parietal bone

The following lines are drawn perpendicular to the base line

The *frontal line* which will be tangential to the inner table of the frontal bone, the *venous angle vertical*, through VA, and the *occipital line*, which is made tangential to the inner table of the occipital bone

The following distances were measured in millimeters and half millimeters
 FP—VA = frontal distance, TS—VA = tuberculum sellae distance, OP—VA = occipital length (L), BP—VA = basal distance

the length and height measurements by plotting (L) against (H) and (h) against (H). The range of the venous angles in a fronto occipital direction in relation to skull length (chart I) and the range in vertical direction in relation to skull height (chart II) are shown in Fig 3. The regression line in each chart is identical with the y- and x axes, respectively in Fig 7, in which the charts are integrated. Each venous angle was plotted in relation to the coordinates y and x. The range of variation (prediction area) is limited by ellipses obtained by multivariate analysis. These were calcu-

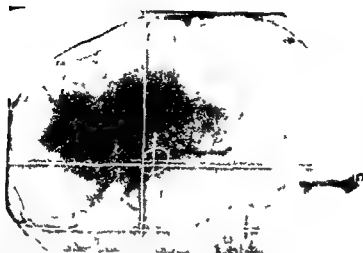


Fig. 9 Venous angle with marked anterior location due to dolichocephaly, skull long posteriorly, the venous angle lies within the 99 % prediction area. Cross in center of ellipse denotes the calculated position.

lated with 99 % probability ($P = 0.01$) and 95 % probability ($P = 0.05$), as shown in the statistical calculations. The large ellipse measures 16.4 mm/13.2 mm and the small ellipse 13.4 mm/10.5 mm, and their areas are 169 mm² (99 %) and 110 mm² (95 %), respectively. The axes of the ellipses cut X (identical with the venous angle horizontal) at an angle of 45° (the angle of inclination, see Fig. 8). Owing to the slope of the ellipse, the maximum range of variation in both vertical and horizontal directions is ± 7.35 mm (99 %) and 5.95 mm (95 %). The maximum distance from the point O along the major axis is 8.2 mm and 6.7 mm, respectively, and along the minor axis 6.6 mm and 5.25 mm, respectively.

Discussion

Earlier methods for determining the physiologic variations of the venous angle in relation to the shape and size of the cranium have already been described. None of them appears to have given acceptable results from the diagnostic standpoint, and the reasons are discussed in connection with the description of the different techniques. The method that seems the best from the aspect of the relevant ellipse area (SCHMITT-WITTKAMP & ROSCHER) was tested by the present author and was found to be unsatisfactory in an unreasonably large number of cases, an error is also inherent in this method. It was therefore necessary to find a technique that would lead to the construction of a topogram having the smallest possible area. Trials with various coordinate systems based on different craniometric points indicated that a rectangular system that took into account the length and height of the cranium but was not dependent on the highly variable

'fixed points' would be the most suitable technique. It was also obvious that the base line of the system should run through the tuberculum sellae, preferably in such a way that the foot of the venous angle vertical (BP) lay close to the tuberculum. The line from the nasion to the opisthion, both of which are nearly always well defined, seemed suitable as the direction line.

Variations in the relation of the nasion to the opisthion may of course affect the direction of the base line and have a rotatory effect on the coordinate system, but this is so small that it can be neglected. The other lines, which form as it were a frame around the skull by making tangents, perpendicular or parallel to the base line, with the anterior, superior and posterior outlines of the cranium, take into account its length and height. A factor having a negative effect on the covariation between coordinates is the relatively large variations in the length of the posterior part of the skull (Fig. 9) and in the upward convexity of the parietal bones. This is especially true of the covariation between basal distance and total height, which is definitely worse than the covariation between frontal distance and total length. In all probability variations in the sella turcica and tuberculum sellae also contribute to this effect. The writer has not found any way of eliminating these factors.

The two charts (Fig. 6) demonstrate that the venous angle amplitudes around the O lines are constant which means that relatively speaking the distribution range (prediction area) is larger for small than for large skulls. To state the variation range in the two major directions as a percentage of total length and total height, respectively, proved to be unsuitable, since the amplitudes around the O lines would then increase with increasing total measurements, with the result that the prediction areas would be much greater for large skulls. This would not correspond with reality, furthermore, it would then not be possible to construct an ellipse of an area applicable to all skull sizes.

The method is relatively simple. Six parallel lines must be drawn, four distances measured, and the position of the venous angle determined in the two charts. With the aid of the value pair obtained, the position of each venous angle can be determined both with respect to distance and direction in relation to the calculated O point.

Conclusion

The physiologic range of variation (prediction area) for the venous angle in the median sagittal plane is elliptic. The axis of the ellipse cuts the base line of the measuring system at an angle of 45° . The ellipse area calculated for 99% probability ($P=0.01$) is 169 mm^2 , its long axis measuring 16.4 mm , and the short axis 13.2 mm . The corresponding values for 95% probability ($P=0.05$) are 110 mm^2 , 13.4 mm and 10.5 mm .

Statistical calculations

Estimations Regression analysis based on 216 measurements gave the relations

$$h = 14.5 + 0.4395H + \epsilon$$

$$l = 4.7 + 0.3914L + \delta$$

where h , H , l , L are defined as shown in Fig. 5 and (ϵ, δ) are assumed to have a bivariate normal distribution with zero means

$$(\epsilon, \delta) \sim N(0, 0, \sigma_\epsilon, \sigma_\delta, \rho)$$

The parameters σ_ϵ , σ_δ and ρ have been estimated to

$$\sigma_\epsilon \approx 2.45 \quad (\text{actually } 2.43)$$

$$\sigma_\delta \approx 2.45 \quad (\text{actually } 2.47)$$

$$\rho \approx 0.254$$

Prediction areas Using results from multivariate analysis prediction areas will be constructed for a new healthy patient's deviations from the regression lines

Let

$$y_i = \begin{pmatrix} \epsilon_i \\ \delta_i \end{pmatrix} \quad i = 1, 2, \quad n = 216$$

be the measured deviations from the regression lines. We now make the simplifying assumption that y_i are independently normal distributed. Then

$$\bar{y} = \frac{1}{n} \sum_{i=1}^n y_i$$

and

$$S = \frac{1}{n-2} \sum_{i=1}^n (y_i - \bar{y})(y_i - \bar{y})$$

are independent

Let now

$$y = \begin{pmatrix} \epsilon \\ \delta \end{pmatrix}$$

be the deviations from the regression lines of a new healthy patient who is to be measured. Then

$$(y - \bar{y})' S^{-1} (y - \bar{y}) \sim \frac{n(n-2)}{(n+1)(n-2) - 2}$$

is distributed according to the F distribution with $2 = 2$ degrees of freedom

This gives the following ellipses within which y will fall with 95%, respectively 99% probability

$$\epsilon^2 + \delta^2 - 0.508 \epsilon \delta - 34.8 \quad 95\% \text{ area}$$

$$\epsilon^2 + \delta^2 - 0.508 \epsilon \delta - 53.9 \quad 99\% \text{ area}$$

Acknowledgements

The author wishes to thank Mr Urban Hjorth who carried out the statistical analysis of the data. This investigation was supported by a grant from the Faculty of Medicine of the University of Umeå.

SUMMARY

Attention is drawn to the importance of the deep cerebral veins in the diagnosis of space occupying lesions or other pathologic states by cerebral angiography and a brief description of the normal anatomy and variations of these vessels is given. The so-called false venous angles are discussed. The author presents his own method for determining the physiologic range of variations in the position of the venous angle in the median sagittal plane.

ZUSAMMENFASSUNG

Der Wert der tiefen Gehirnvenen für die Beurteilung expansiver und anderer pathologischer Veränderungen des Gehirns bei cerebraler Angiographie wird betont. Die Anatomie dieser Gefäße und deren Variationen werden kurz beschrieben und besondere Aufmerksamkeit wird dem sog. falschen Venenwinkel gewidmet. Der Autor gibt seine eigene Methode zur Abschätzung des physiologischen Bereiches der Variationen in der Lage des venösen Winkels in der medialen Sagittalebene an.

RÉSUMÉ

L'auteur attire l'attention sur l'importance des veines cérébrales profondes dans le diagnostic par angiographie cérébrale des processus expansifs ou des autres états pathologiques et fait une brève description de l'anatomie normale et des variations de ces vaisseaux. Il étudie ce qu'on appelle les faux angles veineux. L'auteur présente sa méthode personnelle pour déterminer l'intervalle physiologique des variations de la position de l'angle veineux dans le plan sagittal médian.

REFERENCES

- BERGERHOFF W. Wachstum und Bauplan des Schädels im Röntgenbild. *Fortschr. Röntgenstr.* 79 (1953) 745.
- BRANDT P. Über die Lage des Foramen Monro im normalen und pathologischen seitlichen Phlebogramm und über die Verlagerung der tiefen inneren Venen bei pathologischen Prozessen des Grosshirns. *Zbl. Neurochir.* 19 (1959) 130.
- CLARY R. W. and CLIBRETH G. G. The normal cerebral angiogram. *Amer. J. Roentgenol.* 65 (1951) 345.
- FISCHER E. Eine neue Methode zur Lokalisation des Angulus Venosus der tiefen Hirnvenen unter Berücksichtigung der Form des Schädels. *Acta neurochir.* 14 (1966), 54.
- JOHANSSON C. The central veins and deep dural sinuses of the brain. An anatomical and angiographic study. *Acta radiol.* (1954) Suppl. No. 107.
- LAINE E., DELANDISHIER J. M., GALIBERT P. and DELANDISHIER G. Phlebography in tumors of the hemispheres and central gray matter. *Acta radiol.* 46 (1956), 203.
- LIN P. M., MOKROHNSKY J. F., STAUFFER H. M. and SCOTT M. The importance of the deep cerebral veins in cerebral angiography. *J. Neurosurg.* 12 (1955) 256.
- MASPLES P. F. and DONFANI G. Flebografia cerebrale normale e patologica. (In Italian.) *Acta neurochir.* 3 (1959) 147.

- MOKROHISKY J F, PAUL R E, LIN P M and STAUFFER H M The diagnostic importance of normal variants in deep cerebral phlebography *Radiology* 67 (1956), 34
- RING A Variations in the striate and other cerebral veins affecting measurements of the 'venous angle' *Acta radiol* 52 (1959), 433
- SCHMITT-WITTKAMP F und ROSCHER M Zur Lagebestimmung des 'Angulus venosus' im seitlichen Phlebogramm *Fortschr Röntgenstr* 105 (1966), 92
- UMBACH W Untersuchungen zur Phlebographie der Hirngefäße *Fortschr Röntgenstr* 77 (1952), 179
- VASTINE J H and KINNEY K K The pineal shadow as an aid in the localization of brain tumors *Amer J Roentgenol* 17 (1927), 320
- WOLF B S and HUANG YUN PENG The subependymal veins of the lateral ventricles *Amer J Roentgenol* 91 (1964), 406
- NEWMAN C M and SCHILFSINGER H The diagnostic value of the deep cerebral veins in cerebral angiography *Radiology* 64 (1955), 161

FROM THE ROENTGEN DEPARTMENTS (DIRECTOR HENRY W. GILLESPIE), OF THE
NORTH WEST SURREY GROUP OF HOSPITALS, THE INSTITUTE OF DIRECTORS AND
B.L.P.A. MEDICAL CENTRE, LONDON, ENGLAND

ROUTINE ABDOMINAL RADIOLOGY IN PERIODIC HEALTH EXAMINATIONS

by

HENRY W GILLESPIE

Periodic health examinations have four main objects: detecting disease, establishing a baseline from which subsequent changes can be accurately assessed, forming the basis of research into normality for various groups of the population, and of reassuring the patient that, in the present state of our knowledge, he or she is in reasonably good health.

Chest radiography is an established procedure in presymptomatic diagnosis, but abdominal radiographic survey, although considered necessary with urography and cholecystography, is not widely used as a routine procedure. In the United States a survey of 500 abdominal examinations in patients over 40 years of age, revealed significant, yet clinically unapparent pathology in seven per cent (ROSENBAUM, LIEBER, HANSON & PELLEGRINO 1964). Abdominal radiography fits in well with other screening tests, such as a detailed medical and environmental history, cardiography, exercise cardiorespiratory

A detailed full abdominal roentgen survey provides however

- MOKROHISKY J. F., PAUL R. E., LIN P. M. and STAUFFER H. M. The diagnostic importance of normal variants in deep cerebral phlebography *Radiology* 67 (1956), 34
- RING A. Variations in the striate and other cerebral veins affecting measurements of the 'venous angle' *Acta radiol* 52 (1959), 433
- SCHMITT-WITTKAMP E. und ROSCHER M. Zur Lagebestimmung des 'Angulus venosus' im seitlichen Phlebogramm *Fortschr Röntgenstr* 105 (1966), 92
- UMBACH W. Untersuchungen zur Phlebographie der Hirngefäße *Fortschr Röntgenstr* 77 (1952), 179
- VASTINE J. H. and KINNEY K. K. The pineal shadow as an aid in the localization of brain tumors *Amer J Roentgenol* 17 (1927), 320
- WOLF H. S. and HUANG YUN PENG. The subependymal veins of the lateral ventricles *Amer J Roentgenol* 91 (1964), 406
- NEWMAN C. M. and SCHLESINGER H. The diagnostic value of the deep cerebral veins in cerebral angiography *Radiology* 64 (1955), 161

Table 3

Percentage of congenital spinal abnormalities in cases with and without backache

	Congenital abnormalities		No congenital abnormalities	
	Cases	Per cent	Cases	Per cent
Backache	30	5	538	95
No backache	193	5	3 769	95
Total	220	5	4 307	95

Table 4

Percentage of scoliosis in cases with and without congenital spinal abnormalities

Age group	<35	35-44	45-54	55-64	>65	Total
No congenital abnormality	6 %	6 %	7 %	9 %	7 %	7 %
Congenital abnormality	17 %	18 %	18 %	19 %	67 %*	19 %
Total	6 %	6 %	7 %	9 %	8 %	7 %

* The figure is unreliable owing to the small number of cases

in frequency with the age groups, may not be of clinical significance, but in several instances the position of such calculi may indicate enlargement of the prostatic gland, with subsequent urography demonstrating retention of contrast medium in the bladder after micturition. The absence of gas or displacement of gas-filled organs has often led to further investigation and the persistent presence of excess gas proximal to the sigmoid colon has sometimes been the first indication of stenosing or inflammatory lesions. However, in the majority of patients, excess of intestinal gas may prove to be a constitutional factor and remain remarkably constant over the years. The persistent distribution of the intestinal gas in some individuals as part of their body build emphasises the difficulty in reducing the intestinal gas either by diet or medication as a preliminary to radiographic abdominal procedures.

Although a survey of the skeletal system from an anteroposterior radiogram of the abdomen is limited, it provides information on congenital, positional, or degenerative changes in the lumbar spine which, if clinically necessary, will lead to extended examination of the lower part of the spine. Similarly, the pelvis in an abdominal radiogram may afford an indication of any changes in

Table 1

Percentage of positive findings in abdominal survey films of male executives

Age group	<35	35-44	45-54	55-64	>65	Total
Number of cases	448	1 539	1 560	882	98	4 527
Urinary or biliary calculi	0 %	1 %	1 %	2 %	5 %	2 %
Excess gas in gut	<1 %	1 %	1 %	2 %	1 %	1 %
Prostatic calculi	1 %	4 %	7 %	10 %	13 %	6 %
Scoliosis	7 %	6 %	8 %	10 %	7 %	7 %
Congenital spinal abnormalities	4 %	5 %	5 %	5 %	3 %	5 %
Degenerative bone changes	1 %	2 %	7 %	19 %	36 %	8 %
Arterial calcifications	0 %	1 %	6 %	14 %	29 %	6 %

Table 2

Percentage of backache with skeletal degenerative changes

Age group	<35	35-44	45-54	55-64	>65	Total
Number of cases	448	1 539	1 560	882	98	4 527
Backache	2 %	7 %	10 %	25 %	25 %*	568 13 %
No backache	1 %	2 %	6 %	17 %	37 %	3 959 7 %

* The figure is unreliable owing to the small number of cases

a range of information on the gastro-intestinal, skeletal, and vascular systems, as well as on the genito-urinary tract, and may moreover reveal a significant number of hidden changes

Table 1 presents positive findings in routine abdominal survey films in a series of 4 527 men, according to age groups, examined during the last four years. Whilst the detection of latent abnormalities is of particular importance in the lower age groups, as is to be expected, there is a proportionate increase of abnormalities in older men.

Conventional radiography will reveal alteration in the size and position of soft-tissue organs, such as the kidneys, liver or spleen, or the presence of a space-occupying lesion. In 18 out of a series of 2 000 routine abdominal films, alteration of the renal outline led to further investigation by urography with positive results. Equally the detection of renal stones or gallstones will not only require further radiographic and clinical investigation, but may lead to reassessment of clinical symptoms that previously were considered insignificant by the patient or examining doctor. The presence of prostatic calcifications, increasing

Table 7

Percentage of arterial calcification and ECG in cases with calcification of the iliac arteries

Age group	<35	35-44	45-54	55-64	>65	Per cent of total calcifications
Normal ECG	—	1%	6%	14%	14%	5%
Minor abnormality of ECG	1%	2%	7%	13%	37%	8%
Major abnormality of ECG	—	8%	7%	22%	29%	13%

of the right and left internal and external iliac arteries lend support to the postulation that arterial calcification is not only due to disturbed lipid metabolism but also a mechanical one, a view that has been held by pathologists from the last century. In a flowing system such as the arteries, static zones form at arterial 'L' and 'Y' branchings, as has been demonstrated by experimental evidence (Fox & Hugh 1966 and 1969). Mesenteric calcifications, phleboliths, or ureteric stones are a differential diagnostic alternative to calcifications in the iliac arteries, but calcified plaques, which frequently tend to be bilateral and at the same level, usually provide little diagnostic difficulty. There is an association between arterial iliac calcifications and a raised blood pressure in all age groups. With arterial iliac calcifications, in the total age group four per cent had a systolic blood pressure of less than 145, but ten per cent had systolic blood pressure of more than 145. There is also a statistical higher mean value of cholesterol level in those with calcification in the iliac arteries as compared with those with no evidence of arterial calcification. With normal ECG findings an incidence of five per cent of arterial iliac calcifications was found. In patients with a minor ECG abnormality the incidence of arterial iliac calcifications rose to eight per cent, and with a major ECG abnormality to thirteen per cent. In the clinically significant group between 35 and 44 years of age, one per cent arterial iliac calcifications were found with a normal ECG, but the ECG group with a major abnormality had an incidence of eight per cent. The relationship of electro-cardiographic abnormalities and arterial iliac calcifications is thus a significant and sometimes early diagnostic factor in the detection of degenerative cardio-vascular disease.

Acknowledgements

The author would like to thank H. B. Wright and G. Pincherle for their help in supplying the statistical computer data.

Table 5
Calcified iliac arteries and their relation to blood pressure

Age group	35-44	45-54	55-64	All ages
Systolic blood pressure <145	1 %	5 %	11 %	4 %
Systolic blood pressure \geq 145	3 %	8 %	18 %	10 %

Table 6
Mean cholesterol levels in cases with calcification of the iliac arteries

Age group	35-44	45-54	55-64	All ages
Arterial calcification	277	271	277	273
No arterial calcification	251	257	257	253
t	2.44	2.89	4.25	6.65
P	<0.02	<0.001	<0.0001	<0.0001

the sacro-iliac and hip joints. Radiologic changes due to osteoarthritis of the lumbar spine have little bearing on the severity of backache, but the figures in Table 2 indicate a relationship of osteoarthritis and the presence of backache in all age groups.

Congenital abnormalities in the spine, especially the transitional lumbosacral vertebra, are frequently a pre-disposing factor in disc prolapse (GILLESPIE 1949), although there is no reliable evidence that a congenital abnormality is a cause of backache. On the other hand, the presence of congenital abnormalities, such as a transitional lumbosacral vertebra, spina bifida, or six lumbar-type vertebrae, bears a relationship with lumbar scoliosis in all age groups.

The presence of early arterial calcification in abdominal radiography provides an important clue to cardio-vascular degeneration, which is of special significance if found in a younger age group. It is a pointer to cardio-vascular disease, to be corroborated by other clinical findings such as raised blood pressure, increased serum cholesterol concentrations or abnormal cardiographic findings. The walls of the iliac arteries are favourite sites for early calcifications and frequently contain calcified plaques before they are apparent in the dorsal or abdominal aorta or in the peripheral vessels. The reasons for early calcification at the bifurcation of the right and left common iliac arteries and again at the bifurcation

ROENTGENOLOGIC-PHOTOMETRIC METHOD FOR BONE MINERAL DETERMINATIONS

by

B ELMAN, K G LJUNGQUIST and U STEIN

The roentgen absorption of bone depends largely on its mineral content, which consists mainly (about 85 %) of calcium phosphate (hydroxyapatite). Roentgenologic 'bone density determination' would thus provide an approximate indication of the calcium content of a bone and enable mineral depletion or deposition to be followed.

The calcium content of a bone may be specifically measured by monochromatic roentgen radiation within the wave length range in which calcium gives an absorption maximum. The limitations of present methods have been discussed by JACOBSSON (1964), *inter alios*. Another principle has been used by OESER & HROKOWSKI (1961) who obtained a high calcium specificity by measuring the difference in absorption between exposures at 45 kV and 250 kV. This calls however for technical equipment that is complicated, expensive, and not available outside special research centres. The same applies to the approach by CAMERON & SORENSON (1963) who used iodine 125 as an essentially monochromatic radiation source.

Many investigators have made use of conventional roentgen apparatus for

Submitted for publication 20 March 1969

SUMMARY

Over 4 000 routine abdominal films of healthy men of all ages examined during a period of four years have been reviewed. The figures presented suggest that in clinical diagnostic terms this procedure is of value. Changes in bones and joints, soft tissues and the digestive and urinary tracts can be assessed and there is a significant relationship between arterial calcification and the blood pressure, cholesterol level and ECG abnormalities.

ZUSAMMENFASSUNG

Eine Durchsicht von 4 000 Routineaufnahmen des Abdomens bei Gesunden aller Altersklassen wurde unternommen. Die Resultate zeigen, dass solche Filme von klinisch diagnostischem Wert sind. Veränderungen in den Knochen und Gelenken, Weichteilen, im Magen, Darmkanal und im Nierensystem können abgeschätzt werden. Es besteht zwischen dem Zusammenhang zwischen der Verkalkung der Beckenarterien und dem Blutdruck, dem Cholesterolverbrauch und elektrokardiographischen Abweichungen.

RÉSUMÉ

L'auteur a passé en revue plus de 4 000 radiographies de l'abdomen d'hommes en bonne santé de tous âges examinés au cours d'une période de quatre ans pour des examens de santé systématiques. Les résultats font penser que cette technique présente un intérêt en matière de diagnostic clinique. On peut déceler des modifications du squelette, des artériologies, des parties molles et des appareils digestif et urinaire; il y a une relation significative entre la calcification des artères iliaques et la pression artérielle, le taux de cholestérol et les anomalies ECG.

REFERENCES

- FOX, J. A. and HUGH, A. E. Localization of atheroma. A series based on boundary layer separation. *Brit Heart J* 18 (1966) 388.
- GILLESPIE, H. W. The significance of congenital lumbosacral abnormalities. *Brit J Radiol* 22 (1949) 270.
- ROSENBERG, H. D., LITNER, A., HANSON, D. J. and PELLEGRINO, E. D. A routine survey roentgenograms of the abdomen of 500 consecutive patients over 40 years of age. *Amer J Roentgenol* 91 (1964) 903.

quantitatively estimating the radiation absorption by the mineral content of bone in a positive or negative roentgen image (see, for instance, OMNELL 1957, NORDIN & SMITH 1965). The problems involved will be considered.

Reproducibility and standardization The absorption effect of the mineral content of bone on the negative or positive roentgen image is affected by exposure time, voltage, screens, type of film for the primary image and the positive print, as well as by the processing and printing technique. Despite advanced automation in roentgen apparatus and processing procedure, and the uniform quality of modern films, the direct correlation of roentgen absorption with mineral content, as it appears in the final image, is impossible. The investigated bone should therefore at each analysis be compared with a standard and the results expressed as a percentage. The choice of a standard has been thoroughly examined. According to OMNELL (1957) roentgen rays are absorbed by aluminium to the same degree as bone mineral. It is thus possible to express the results in millimetre aluminium or, if required, in bone mineral content, for example as hydroxyapatite.

Soft tissue effect and secondary radiation By the choice of adequate radiation quality and suitable film the influence of soft tissue on the negative and positive roentgen image can be much reduced. According to SCHMID (1963), the soft tissue effect is negligible under certain conditions, for instance in the examination of the phalanges of the hand.

KEANE et coll. (1959), working with the radius and ulna, i.e. bones surrounded by thick layers of soft tissue, could avoid most of the side effects by placing the forearm together with the standard in a tank of water and by having an exit distance between arm and standard in the water tank and the film (the same arrangement as in Fig. 6). Even then they had to correct for soft tissue effects in their calculations.

Photometric evaluation Earlier investigators usually employed densitometric determinations pointwise or over defined areas of the bone investigated. However, great difficulties are experienced in anatomically defining the measurement area from one patient to another. To make the measurement independent of the anatomical bone size, two films must be obtained: one for densitometry and one for measurement of the diameter where the bone is traversed by the beam.

Preliminary methodologic investigations

Working with the radius and ulna we found that when an aluminium standard was placed at the side of the forearm, secondary radiation and

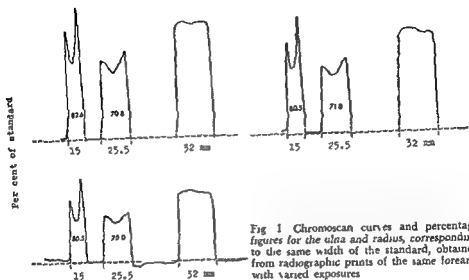


Fig 1 Chromoscan curves and percentage figures for the ulna and radius, corresponding to the same width of the standard, obtained from radiographic prints of the same forearm with varied exposures

scatter effects produced appearances that varied widely from one roentgenogram to another. Despite repeated attempts, this source of error could not be eliminated by enclosing the standard in a phantom — The best results were obtained with a phantom composition, mix D, according to JONES & REIVE (1949), consisting of 60.8% paraffin, 30.4% plastic material (Alkathene Polymer WRM-19, ICI), 2.4% titanium dioxide and 6.4% magnesium oxide — Using the Keane technique however, with the forearm enclosed in a tank of water, we obtained reproducible films of the standard and, as indicated by KEANE, the soft tissue effects became considerably lower.

Soft tissue consists of approximately 75% water, the rest being organic matter with a low roentgen absorption approaching that of water. However, the extra- and intracellular water contains a wide variety of electrolytes, and the present approach was an attempt to eliminate completely the soft tissue effects by adding adequate amounts of quantitatively dominating sodium chloride to the water in the tank.

Difficulties in earlier employed densitometric measurement techniques appeared to be avoided by measuring the blackening in the positive image from a bone cross section by photometric scanning and expressing this in relation to the blackening of the corresponding cross section width of the standard used. This can be easily accomplished technically by employing the same type of photometric scanning equipment that is used at evaluation of electrophoresis strips. The Chromoscan Mark I (Joyce, Loebli & Co Ltd, Gateshead-on-Tyne, England),

quantitatively estimating the radiation absorption by the mineral content of bone in a positive or negative roentgen image (see, for instance, OMNELL 1957, NORDIN & SMITH 1965). The problems involved will be considered.

Reproducibility and standardization The absorption effect of the mineral content of bone on the negative or positive roentgen image is affected by exposure time, voltage, screens, type of film for the primary image and the positive print, as well as by the processing and printing technique. Despite advanced automation in roentgen apparatus and processing procedure, and the uniform quality of modern films, the direct correlation of roentgen absorption with mineral content, as it appears in the final image, is impossible. The investigated bone should therefore at each analysis be compared with a standard and the results expressed as a percentage. The choice of a standard has been thoroughly examined. According to OMNELL (1957) roentgen rays are absorbed by aluminium to the same degree as bone mineral. It is thus possible to express the results in millimetre aluminium or, if required, in bone mineral content, for example as hydroxyapatite.

Soft tissue effect and secondary radiation By the choice of adequate radiation quality and suitable film the influence of soft tissue on the negative and positive roentgen image can be much reduced. According to SCHMID (1963), the soft tissue effect is negligible under certain conditions, for instance in the examination of the phalanges of the hand.

KEANE *et coll.* (1959), working with the radius and ulna, i.e. bones surrounded by thick layers of soft tissue, could avoid most of the side effects by placing the forearm together with the standard in a tank of water and by having an exit distance between arm and standard in the water tank and the film (the same arrangement as in Fig. 6). Even then, they had to correct for soft tissue effects in their calculations.

Photometric evaluation Earlier investigators usually employed densitometric determinations pointwise or over defined areas of the bone investigated. However, great difficulties are experienced in anatomically defining the measurement area from one patient to another. To make the measurement independent of the anatomical bone size, two films must be obtained, one for densitometry and one for measurement of the diameter where the bone is traversed by the beam.

Preliminary methodologic investigations

Working with the radius and ulna we found that when an aluminium standard was placed at the side of the forearm, secondary radiation and

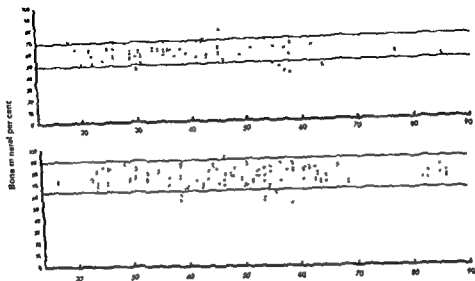


Fig 3 Referen
 ject represent
 corresponds to a

tark Fig 2, in which the aluminium thickness is plotted against Chromoscan readings, shows that full linearity is obtained, although lighter or darker prints were produced by deliberately varying the exposure time in the copying procedure

The reproducibility of the method was investigated in twelve separate determinations of the bone mineral percentage in a section of a foreleg of a pig. The mean was found to be 81.9 with SD 3.4 and a coefficient of variance of $\pm 4.1\%$.

The problem was then, with a reasonably simple and reproducible method available for determining the roentgen ray absorption of bone tissue, what the clinical and biologic significance of its use would be.

In diseases with a reduced mineral content in the skeleton, and when the conventional roentgen technique is employed, this depletion is mainly observed in the spinal column. Considerable variations in the mineral content are however necessary before such changes can be recorded, figures in the order of 30 to 50% usually being suggested. Although changes in the mineral content are perhaps most marked in the spinal column, it seems probable that if caused by diet or by endocrine factors they will affect the skeleton as a whole and can be demonstrated provided a sufficiently sensitive method can be employed.

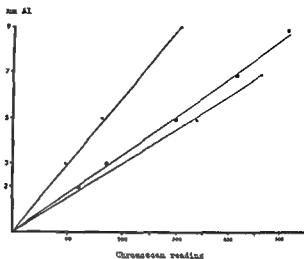


Fig. 2 Correlation between aluminium layer thickness and Chromoscan readings at different exposure times

a double beam recording and integrating reflection photometer that makes it possible to integrate numerically any chosen part of the areas under the density curves, was chosen for our purpose.

The forearm of the patient and an aluminium standard, in fixed positions in 0.86 % saline, 10 cm in depth, are roentgenographed at suitable voltage and exposure time with a hard film, eliminating the effects of soft tissue. Secondary radiation effects are relatively slight because of the 30 cm space between the water tank and the cassette holder (see Fig. 6).

The blackening in the positive film is determined in two cross sections, one at the centre of the radius and ulna and the other in the vicinity of the distal joint heads by scanning with the Chromoscan. The degree of blackening of the bones is expressed as a percentage of the blackening of a corresponding width of the aluminium standard. By suitable shaping of the wedge in the Chromoscan linearity between the degree of blackening and the thickness of the plates in a series of aluminium standards can be obtained. The technical procedure is described later.

The control experiments indicated that by varying the exposure time at copying, but keeping other conditions constant, prints with different blackening will be obtained. This does not however affect the measurement results (Chromoscan readings of the bone curves as percentages of the readings of corresponding widths of the aluminium standard). A typical example is given in Fig. 1.

Linearity between the roentgen absorption and the Chromoscan readings was controlled by roentgenographing a series of aluminium plates, of different thicknesses but otherwise of the same shape, arranged side by side in the

Table I

Comparison of bone mineral percentages for the left and right arms

Number of patients	Right or left handed	Mean values and left/right ratios							
		Radius				Ulna			
		Strip-I		Strip-II		Strip I		Strip-II	
		Left	Right	Left	Right	Left	Right	Left	Right
10 females	Right	47.7	52.6	32.2	57.5	46.1	51.1	51.7	58.3
		0.91		0.91		0.90		0.89	
10 males	Right	67.0	70.6	48.2	80.9	64.5	67.2	81.4	84.4
		0.95		0.97		0.96		0.96	
2 males	Left	60.0	55.6	71.8	64.6	58.8	50.9	81.8	72.9
		1.08		1.11		1.15		1.12	

might not per se imply mineral disorders), and whom for several years had been given cortisone preparations without accompanying treatment with calcium preparations or anabolic steroids, were therefore investigated. The values of most of the patients lay within the lower part of the normal range. Those judged clinically to be suffering from osteoporosis were far below (Fig 4, a and b). Partial gastrectomy may result in malabsorption of calcium (HARVALD, BROGSGAARD & LOUS 1962). Bone mineral percentages for males who had had Billroth II operations are given in Fig 4 c. They all have readings below the mean value and most of them around the lower normal range.

Like KROKONSKI & STEINER (1961) we regularly found higher values of the mineral content in the right than in the left arm in right handed subjects and vice versa (Table 1). HEANE et al. (1959) pointed out the dependence of calcium deposition on mechanical factors which might well explain the findings.

The well known fact that immobilization results in a reduction of calcium is illustrated in Fig 5, which gives the bone mineral percentages in a patient with a radius fracture of the right arm on the day it occurred, after 24 days immobilization, and again after a further 19 days convalescence. It is obvious that, whereas values in the undamaged left arm were constant or somewhat increased, a substantial reduction occurred in the right arm, even during the short immobilization period, followed by a return to the initial values.

These results — the low values in bone mineral content in clinically diagnosed osteoporosis, and the decrease during cortisone medication, after gastrectomy,

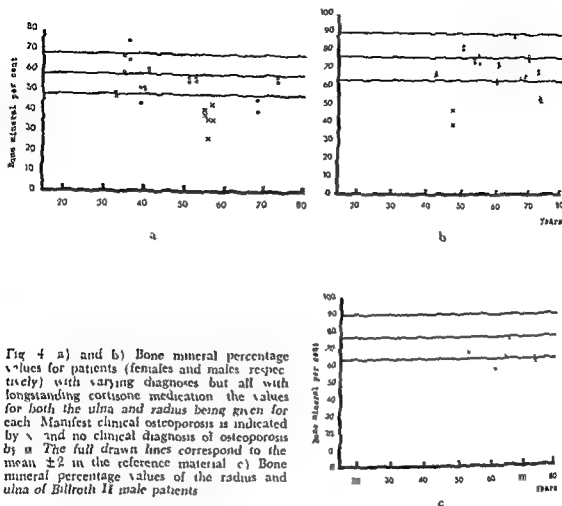


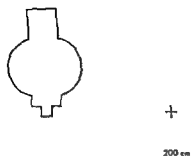
Fig 4 a) and b) Bone mineral percentage values for patients (females and males respectively) with varying diagnoses but all with longstanding cortisone medication the values for both the ulna and radius being given for each. Manifest clinical osteoporosis is indicated by \times and no clinical diagnosis of osteoporosis by \square . The full drawn lines correspond to the mean ± 2 in the reference material c) Bone mineral percentage values of the radius and ulna of Billroth II male patients

The best way to test the method seemed to be to investigate the clinical conditions in which changes in the bone mineral content might be expected.

A preliminary reference series of 61 females and 80 males of different ages was collected. The results are given as bone mineral percentages in Fig 3. For definition and calculation, see p 316. The mean ± 2 SD is the normal range.

As can be expected in a reference series of hospital subjects, a few patients lie outside the normal range (5 females and 4 males). Closer analysis of these revealed that most of them had histories of dietary insufficiencies. The female with the lowest values, for instance, was an alcoholic who had lived for a long period mainly on red wine and industrial spirit.

As is well known, cortisone therapy may result in a reduced bone calcium content. Patients admitted to the hospital under varying diagnoses (which usually



200 cm

PLEX GLAS CONTAINER



+

10 cm

+

30 cm

CASSETTE AND INTENSIFYING SCREENS



+

Fig 6 Arrangement of the equipment and some technical data Exposure with 70 kV, 200 mA and 0.1 second

The arrangement during exposure is illustrated in Fig 6 together with the technical data

Procedure The forearm is placed in a plexiglas container filled with sodium chloride solution. The inner base is 10×30 cm and the height 40 cm. The lower part contains a plastic tube that the patient grips, the tube being furnished with a collar to ensure that the arm is in a position fixed in relation to an aluminium standard ($0.7 \text{ cm} \times 2.7 \text{ cm} \times 23 \text{ cm}$) in the container. The central ray must be directed through the centre line of the forearm. Films of the left and right arms are obtained. A 0.86% sodium chloride solution is used and it has proved practical to add 7.5 g metagin and 2.5 g nipasol per 10 litres to prevent rapid bacterial growth.

Standard cassettes with intensifying screens keep the radiation hazards to a minimum. Gevaert Cronix roentgen film, emulsion type T, and a standard automatic processing unit are employed. Two parallel-coupled knives cut the film into 27 mm strips for the Chromoscan holder, a marking arrangement indicating suitable lengths of strip. To ensure that these will correspond anatomically to comparable parts of the radius and ulna in different subjects, the

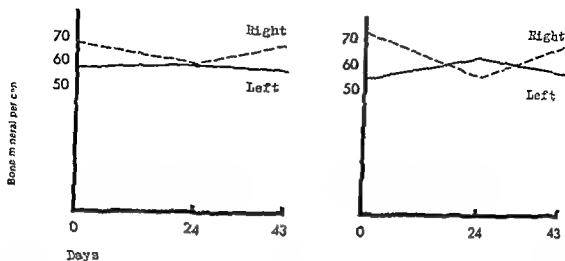


Fig. 5. Bone mineral percentage values of the radius (left) and ulna (right) from a woman on the day of fracturing the right radius after 24 days immobilization and after an additional 19 day period of convalescence

during immobilization, as well as the higher mineral content of the bones on the work hand side — may be regarded as establishing the clinical usefulness of the method

The necessity of evaluating positive copies instead of the original roentgen films must however involve the added errors and the extra manual work of an additional photographic procedure, and the disadvantage of photometrically measuring reflected light in place of transmitted light. Our work was performed during the period 1964—1966, and in 1966 the new Chromoscan Mark II became available. This model has been designed also for transmittance measurements, the new feature was taken advantage of and by simply turning the (transparent) grey wedge 180° it was possible to make the apparatus read (and give integrals of) white instead of black areas. It thus became possible to obtain Chromoscan readings direct from the original negative roentgen film

Present method

Principle of measurement The modified method differs from the preliminary version used in the photometric measurements. The roentgen absorption by bone or standard is measured directly in the film with the aid of a Chromoscan Mark II transmittance photometer which after reversing the grey wedge gives positive curves and readings of the negative bone and standard image in the film.

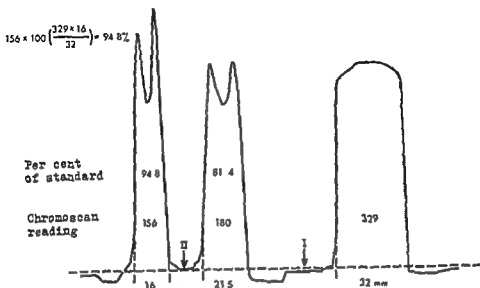


Fig 8 Chromoscan curves corresponding to strip from film of ulna, radius and standard

The apparatus is set at zero at a point a few centimetres from the standard, between this and the soft tissue of the arm (Fig 8, arrow-I). The apparatus is thus constantly at zero on the water layer. With the chosen saline concentration, an even base line for the fluid and for the soft tissue between the radius and ulna is obtained, with a deviation only for the layer of fat of the soft tissue which appears as downward curves at the base line of Fig 8.

The base line is drawn out (as seen in Fig 8) and with our technique a width of the standard of 32 mm is obtained. The width of the radius and ulna is measured at the level of the base line with a pair of calipers graded to 0.1 mm. As may be seen from the figure, the straight lateral parts of the bone curves are drawn down towards the base line to eliminate difficulties of measurement caused by the rounding of the bone contour immediately next to the base line.

In extremely obese or thin people, some level difference may appear between the soft tissue line lying between the radius and ulna (Fig 8, arrow-II) and that part of the base line that corresponds to the fluid (arrow-I). If this exceeds 6 mm, two zero adjustments are made: the normal at arrow-I for scanning the standard and another at arrow-II, based on the soft tissue between the radius and ulna, for scanning the bones.

The integration figures are noted for the curves of the standard and for

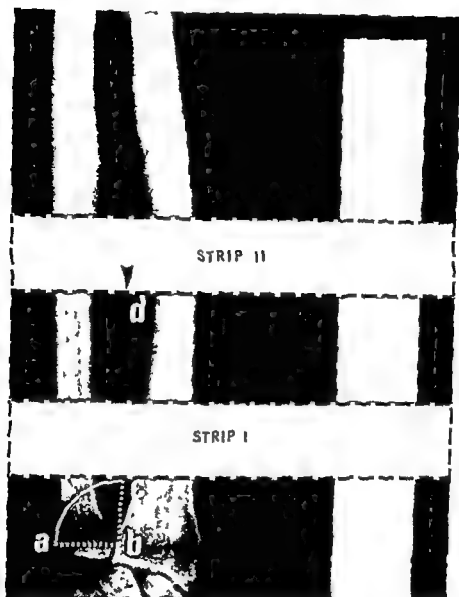


Fig. 7 Positioning of the strips

greatest width of the distal joint of the ulna is measured. This length (A—B) (Fig. 7) is plotted along the ulna, the first strip being cut from point C. The measured distance A—B is quadrupled, and strip No. 2 is cut from point D. Thus two strips are obtained, one corresponding to a more cancellous bone and the other to a bone in which the compact tissue dominates. The film strip is placed in the holder of the Chromoscan Mark II adapted for transmittance measurements and with its grey wedge turned 180°, as described. Filter 25 D and a slit measuring 1 mm \times 10 mm are the rule.

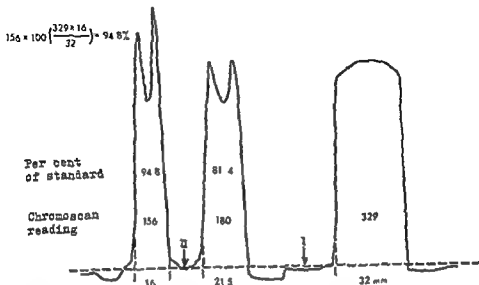


Fig 8 Chromostan curves corresponding to strip from film of ulna, radius and standard.

The apparatus is set at zero at a point a few centimetres from the standard, between this and the soft tissue of the arm (Fig 8, arrow-I). The apparatus is thus constantly at zero on the water layer. With the chosen saline concentration, an even base line for the fluid and for the soft tissue between the radius and ulna is obtained, with a deviation only for the layer of fat of the soft tissue which appears as downward curves at the base line of Fig 8.

The base line is drawn out (as seen in Fig 8) and with our technique a width of the standard of 32 mm is obtained. The width of the radius and ulna is measured at the level of the base line with a pair of calipers graded to 0.1 mm. As may be seen from the figure, the straight lateral parts of the bone curves are drawn down towards the base line to eliminate difficulties of measurement caused by the rounding of the bone contour immediately next to the base line.

In extremely obese or thin people, some level difference may appear between the soft tissue line lying between the radius and ulna (Fig 8, arrow-II) and that part of the base line that corresponds to the fluid (arrow-I). If this exceeds 6 mm, two zero adjustments are made: the normal at arrow-I for scanning the standard and another at arrow-II, based on the soft tissue between the radius and ulna, for scanning the bones.

The integration figures are noted for the curves of the standard and for

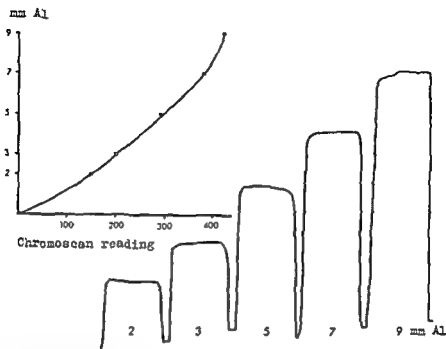


Fig 9 Chromoscan chart of a series of aluminium plates and the curve obtained by plotting Chromoscan readings against aluminium layer thickness. Uncorrected cam

the radius and ulna. The integration value for each bone is calculated for the corresponding width of the standard, the integration value of the radius and ulna is then expressed as a percentage. The values obtained in such calculations are exemplified in Fig 11.

Experimental The roentgen absorption of soft tissue is mainly conditioned by its water and electrolyte content. The fat in the subcutaneous layer and the bone marrow has a lower roentgen absorption, however. This may explain that 0.86 % saline gave the best equalizing effect, even though the total electrolyte roentgen absorption effect in homogenous soft tissue is higher than that corresponding to the saline concentration chosen.

Exposure time, voltage, type of film, processing procedure, zero adjustment routine, and the effect of base line variations at the Chromoscan measurements were all subjected to detailed investigations.

Ten routine kilovoltage settings were carried out on the apparatus used (Elema Schonander Optimat), and the electrical output differences (with the actual tube load) proved to be less than $\pm 2\%$ at a nominal 70 kV.

The 'reading range' in the film was densitometrically determined and found to be within 1 and 2 in density (i.e. the darkest spot on the film a little below

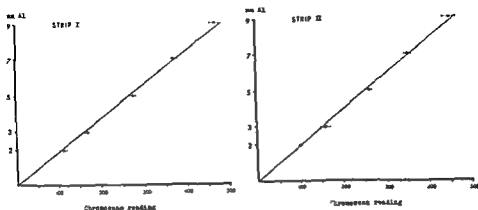


Fig 10 Mean values with their SD's of the transformed Chromoscan readings from eleven films of the same series of aluminum plates plotted against aluminum layer thickness. Corrected cam.

2 and the brightest a little over 1). This means that the fogging of the film within normally accepted ranges has little or no effect on the measurements. Tests with new and old film of the same type disclosed no definite tendency.

The use of intensifying screens introduces possible errors, but without them it was not possible to obtain a sufficient density although different film types were tested. With the best film, a 20 fold increase in radiation exposure gave densities ranging from 0.6 to 1.4, which is far too low. It proved practical to have four cassettes with screens, used exclusively for this kind of work, thus keeping wear down to a minimum. The screens are picked from the same emulsion number and 'cross tested' against each other. Any changing of screens owing to wear naturally demands recalibration of the Chromoscan readings, as does any change of films (emulsion number or type).

Geometric problems and the heel effect were studied, and it was found that by keeping the object and the standard always in the same fixed positions in relation to each other and to the central roentgen beam, the measurements gave reproducible results. Model experiments with isolated bones indicated that variations in projection did not change the measurement results.

A detailed presentation of the experiments is outside the scope of this paper. It may be assumed however that the accumulated effect of the different sources of error could be demonstrated in studies of linearity and the reproducibility of the measurements.

1 *Linearity*. A series of aluminum plates were arranged in the container with the 7 mm plate in the same position as when it was used as standard

Table 2

The reproducibility of the method

Bone mineral percentage 12 separate determinations	Strip I			
	Radius		Ulna	
	Left	Right	Left	Right
Technician I	61.8	67.4	66.5	67.0
Mean				
SD	2.4	3.3	3.2	4.2
Variation				
coefficient	3.8	4.8	4.8	6.3
Technician II				
Mean	59.9	67.3	65.0	67.5

in the bone measurements, and with the thinner plates covering the position occupied by the forearm.

The blackening of the film as a result of roentgen absorption by bone or the aluminium standard (both of which affect the roentgen beam alike (OMNEIL 1957)) depends on the quality of the roentgen beam and the characteristic film response curve varying from one type of film to another. A 'cam' in the Chromoscan controls the pen deflection that results from the effect of the light beam on the photomultiplier. By varying the profile of the cam, it is possible to change the relation between the pen deflection and the blackening to be measured. This means that every film response curve can be adjusted to linearity by means of the cam.

Fig. 9 is a typical reproduction of the Chromoscan chart and the non linear curve obtained by plotting the chromoscan integrated readings against the thickness of the aluminium plates. A linear standard cam was used in this case.

A new cam was constructed, partly calculated according to ALBERT RECHT & OWEN (1964) and partly empirically by repeated measurements of the aluminium plate series and successive changes of the cam. It was thus possible to obtain perfect linearity even in the preliminary two step film positive print method (Fig. 2).

In order to study possible effects of technical and instrumental variations on linearity in repeat measurements with the present method, the aluminium

Table 2 (cont.)

Strip-II				Means of			
Radius		Ulna		Radius Strip I+II Left + Right	Ulna Strip I+II Left + Right	Strip-I Radius + Ulna Left + Right	Strip-II Radius + Ulna Left + Right
Left	Right	Left	Right				
75.8	78.8	90.2	89.2	10.9	78.3	65.4	83.5
2.9	3.8	3.3	3.7	1.1	2.1	2.3	2.0
3.8	4.7	3.6	4.1	1.5	2.7	3.4	2.4
77.0	80.0	91.3	90.8	71.1	78.6	63.0	84.8

plate series was exposed eleven times at intervals with readjustment of the roentgen equipment between the films. The resulting curves for the different films depict slopes varying according to deeper or lighter individual blackening of the films. The mean slope was calculated for all the curves, for each separate curve, a factor was derived to transform the separate reading data to correspond with the curve with the mean slope.

In Fig. 10 are given the mean values of the transformed data from eleven films with their standard deviations plotted against aluminium layer thickness. Data are given for two strips from each film, cut from the same positions as in the bone determinations. A slight systematic deviation from linearity is observed in both strips. This is because the cam for the film used was constructed three months before the experiment, and the deviation could be explained by the replacement of a potentiometer in the integrating circuit of the Chromoscan. The deviation from the original perfect linearity probably reflects the tolerances in the manufacture of the two potentiometers. Every adjustment or replacement in the Chromoscan should obviously be followed by recalibration.

2 Reproducibility. Twelve roentgenograms were taken at intervals of the left and right forearms of the same subject in order to test the reproducibility of our method. Table 2 gives the means of the eight separate measurements and of groups of these with their standard deviations and variation coeffi-

Table 3

Mean bone mineral percentages for radius and ulna in three equivalent groups of women determined with varied techniques

Investigated group	Number	Mean bone mineral percentage Radius and ulna	Method
I Hospitalized females, mainly psychiatric age 18—49 years	43	59.5	Preliminary
II Pregnant (2nd—4th month)	73	59.3	Definite but
III Population study, females age 29—49 years	94	58.7	different films and emuls

cients the means of the four strip-I and the four strip-II measurements, and of the four measurements of the radius and the ulna

The mean variation coefficient for the separate measurements is $\pm 4.0\%$. The higher variation coefficients of some of the strip-I measurements depend on the more irregular contour of the bones in the vicinity of the joints and the resulting greater influence of errors in measuring the width of the bone on the base line.

The mean values of the groups of measurements represent lower variation coefficients and might eliminate hazard errors, both in roentgenography (for instance, localized irregularities of the film) and in the Chromoscan measurements of the bone width.

The means of the four measurements of each bone (left and right arms, strip-I and strip-II of the radius and of the ulna) showed the lowest variation coefficients and were therefore chosen to represent the results in clinical investigations and are called 'the bone mineral percentages' (The individual measurement value will thus express the roentgen ray absorption in the bone cross section investigated as a percentage of the roentgen ray absorption in a 7 mm aluminium plate of the same surface area.) The variation coefficient for the radius was $\pm 1.5\%$ and for the ulna $\pm 2.7\%$.

A comparison between the results when two technicians separately performed the whole Chromoscan procedure on the same strips also appears in Table 2. The agreement was excellent.

The reproducibility of the method may be illustrated in another way by comparing the results from different but equivalent clinical materials (1) females in the reference material (Fig. 3) between 19 and 49 years of age, (2) results obtained for pregnant women on their first visit to the prenatal care unit (2nd to 4th month of pregnancy) from an investigation to determine

Table 4

*Bone mineral percentages of different sex and age groups in a population study***4 Females**

Number	44		50		47		44		38	
Age groups years	25-39		40-49		50-59		60-69		70-79	
Bone	Rad	Ulna	Rad	Ulna	Rad	Ulna	Rad	Ulna	Rad	Ulna
Mean bone mineral %	58.1	57.4	59.6	59.7	54.8	56.0	49.2	50.9	46.7	47.8
Standard error of the mean	0.86	0.75	0.92	1.02	1.08	1.27	1.16	1.14	1.57	1.53
SD	5.7	5.0	6.5	7.2	7.4	8.7	7.7	8.9	9.7	9.4
Range (mean \pm 2 SD)	45.7	47.4	46.6	45.3	40.0	38.6	33.8	33.1	27.3	29.1
	69.5	67.4	72.6	71.1	69.6	73.4	64.6	68.7	66.1	66.2
Per cent of investigated below a bone mineral content of 47 %		—	8	4	19	17	32	32	37	47

B Males

Number	44		35		38		46		37	
Age groups years	29-39		40-49		50-59		60-69		70-79	
Bone	Rad	Ulna	Rad	Ulna	Rad	Ulna	Rad	Ulna	Rad	Ulna
Mean bone mineral %	69.0	69.1	68.7	70.3	66.3	68.1	65.0	68.1	64.6	67.9
Standard error of the mean	0.75	1.01	0.76	1.32	1.13	1.34	1.36	1.28	1.18	1.52
SD	6.3	6.7	4.5	7.8	7.0	8.2	8.8	8.7	7.2	9.2
Range (mean \pm 2 SD)	56.4	55.7	59.6	54.7	52.3	51.7	47.4	51.7	50.2	49.5
	81.6	82.5	77.8	85.9	80.3	84.5	82.6	84.5	79.0	86.3
Per cent of investigated below a bone mineral content of 56 %		—	—	3	5	8	22	11	11	11

possible changes in the mineral content of bone, (3) results corresponding to females 29 to 49 years of age from a population study (see below). From a methodologic point of view, this means that the preliminary method was used (SPRANG 1966) in group I and in groups II and III the definite method (SPRANG & AUTUMN 1967) but with different films. Table 3 indicates good agreement between the three groups, even though for both the Chromoscan Mark I and Mark II three different films and accordingly three different cameras had been used.

Normal range of the method. A population study was performed in order to study the possible correlations between the bone mineral percentage and

sex, age, anthropology, diet and especially calcium intake, activity and the results of a complete clinical, roentgenologic, and laboratory investigation of each participant. The results will be published separately and only the data necessary to establish the normal range of the method will now be mentioned. The participants were picked out by chance from the official registration records by a system that would ensure an even distribution in regard to sex, age, and origin from rural or urban areas, with a number of participants large enough to allow statistical analysis. In all, 484 persons were approached and 87.4% (426) participated. Non attendance was equally distributed in different population groups.

Table 4 gives the means of the determinations of the bone mineral percentage of the radius and ulna for different sex and age groups. The figures are considerably lower in females than in males and, for both sexes, highest in the groups 29 to 49 years. Males had a slow and females a considerable and statistically significant decrease with increasing age. In both sexes, the values for the radius and ulna almost coincide in the age groups up to 49 years but thereafter, the ulna produces somewhat higher figures.

The normal ranges (mean \pm 2 SD) for the different age groups (Table 4) must, in a population study, be influenced by old age osteoporosis. There therefore seems to be justification in choosing the mean of the ranges for the group from 29 to 49 years as the normal for the method, that is 47 to 70% for females and 56 to 80% for males.

Discussion

The object of the methodologic work was to develop a simple technique which, with conventional roentgenologic and laboratory equipment, would produce reproducible results corresponding to the bone mineral content.

This makes it necessary to abstain from the use of monochromatic roentgen radiation, which meant that the absorption effects will not be specific for calcium. This is why no attempt has been made to express the results in milligram calcium per bone area or volume. The measurement figures correspond to total bone minerals of which, however, calcium hydroxyapatite dominates. By expressing the results as percentages of an easily defined and manufactured aluminum standard, however, it seems possible for various investigators to use the method both for diagnostic purposes and for following changes in the bone mineral concentration in the same individual, depending on pathologic changes or therapy.

An attempt has been made to simplify the method by utilizing the technical possibilities of the Chromoscan instrument: the measurement of bone width

■ made directly on the Chromoscan curve underlying the integration reading which, by reversing the grey wedge, is made positive in evaluating the negative film. Furthermore, it has been possible by changing the cam, in accordance with the principle of the Chromoscan instrument, to obtain full linearity between the integration readings and a series of aluminium standards of different layer thicknesses.

The construction of the cam to be used is based on measurements of an aluminium standard series (corresponding to the aluminium step wedge in other methods for obtaining bone mineral content) placed across the area of the film employed for the bone determinations with the forearm and the 7 mm aluminium standard in fixed positions. This means that the cam will eliminate the heel effect, the influence of the inhomogeneity of the roentgen beam over the exposed area and the differences in blackening effect caused by changes in the spectral composition of the beam in passing aluminium (or bone) layers of varying thicknesses.

In conclusion it may be said of the control experiments that the technical specifications chosen maintained the linearity and reproducibility of the method, despite the unavoidable variations of a technical nature that must occur in the complex working procedure of both roentgenography and Chromoscan measurements. This in turn depends on the main principle of the method, all technical variations will affect bone and standard alike.

During the progress of our work, ANDERSSON, SHIMMINS & SMITH (1966) published a method for the measurement of the metacarpal mineral content with the Chromoscan Mark II. These authors evaluated the 'density' by graphically projecting the curve of bone on that of an aluminium step wedge. The density was then correlated to bone width and cortical thickness measured on the film, and a 'standardised aluminium equivalent' of the bone calculated (in principle corresponding to our bone mineral percentage).

We have also applied our method to metacarpal measurements. The smaller width of metacarpal bones made it necessary to change the gear controlling the speed of the chart drum in order to obtain reproducible results.

A survey of methods proposed for clinical studies of changes in bone mineral contents was given by NORDIN & SMITH in their 1965 monograph. The technical difficulties and low reproducibility, however, have prevented the suggested determinations from coming into general use. As stated by these authors, so far no control series that permit systematical clinical investigations have been presented. ANDERSSON, SHIMMINS & SMITH (1966) reported that the establishment of normal ranges for their method is in progress.

KROKOWSKI & STEINER (1961), using the method of OESER and KROKOWSKI (1961) with high calcium specificity, found a decrease in calcium concentration

of the radius in ageing females, which agrees well with the decrease demonstrated in Table 4. Contrary to the present findings they observed the same tendency in males but this may be explained by the small number of more elderly males in their material (Altogether they investigated 50 females and 45 males). They found, as did the present authors, lower values for females than for males. The figures for females of middle age groups amount to 87 % of the figures for males. The corresponding figure in the present material is 85.5 %.

Table 4 gives the percentages of subjects falling below the normal range of the method for each age group (corresponding to the age groups 29 to 49 years). For females there is a regular increase up to about 40 % for the higher age groups, whereas males present much lower percentage figures. The results agree well with the frequency of senile osteoporosis reported by BECK & NORDIN (1960) and GITMAN, KAMHOLTZ & LEVINE (1958).

The main part of our knowledge concerning calcium metabolism originates from balance experiments, which, however, in principle, mainly provide information about the relation between Ca input and Ca output and only indirectly about deposit and depletion in the skeleton. The technical difficulties and errors of calcium experiments have recently been stressed by ISAKSSON, LINDHOLM & SJÖGREN (1966).

The concept of osteoporosis is consequently controversial. Mention will be made only of the view of the Albright School, which regards osteoporosis as being caused by an endocrinely conditioned protracted removal of the organic basic substance of the skeleton, as opposed to the increasingly widely held theory on osteoporosis as a calcium deficiency condition. The slight decrease in the bone mineral content in ageing males and the considerable decrease in elderly females found in the present population study seem to emphasize endocrinologic factors, possibly the cessation of estrogen production in females after the menopause.

Acknowledgement

The authors take this opportunity of thanking E. Carlström, Lecturer at the Department of Statistics, University of Gothenburg, who gave the principles for sampling in the population study, and A. Anberg and T. Leonhardt for their cooperation and help. The work was supported by Ålsborgs Lans Landsting and AB Leo's Foundation for Research, Helsingborg.

SUMMARY

A new, technically simple method of determining the mineral content of the radius and ulna is reported. This demands only standard equipment for roentgen films and for photo-metric scanning. Normal ranges for males and females of different ages were recorded in a population study of 426 subjects and agree with those in the literature on the incidence of senile osteoporosis.

ZUSAMMENFASSUNG

Eine neue und einfache Methode zur Bestimmung des Mineralgehaltes von Radius und Ulna wird angegeben. Diese Methode erfordert lediglich normale Röntgenapparatur und zusätzlich Einrichtung für ein photometrisches Scam. Die Methode wurde an 426 Personen (gleiches Alter und Geschlecht) angewandt. Die Befunde stimmten mit den in der Literatur gefundenen gut überein, auch bezüglich der Häufigkeit der senilen Osteoporose.

RÉSUMÉ

Les auteurs présentent une nouvelle méthode techniquement simple pour déterminer la teneur en minéraux du radius et du cubitus. Elle nécessite seulement un équipement ordinaire de radiographie et de photométrie. Ils ont déterminé les variations normales chez les hommes et chez les femmes, à différents âges dans une étude de population de 426 sujets. Ces résultats concordent avec les résultats déjà publiés dans la littérature sur la fréquence de l'ostéoporose sénile.

REFERENCES

- ALBERT RECHT F and OWEN J A: Correction for non linearity in the response of the chromoscanner. *Clin chim Acta* 10 (1964) 577
- ANDERSON J B, SHIMMENS J and SMITH D A: A new technique for the measurement of metacarpal density. *Brit J Radiol* 39 (1966) 443
- BECK J S and NORDIN B E C: Histological assessment of osteoporosis by iliac crest biopsy. *J Path Bact* 80 (1960) 391
- BOURNE G E: The biochemistry and physiology of bone. Academic Press, New York 1956
- CAMERON J R and SORENSON J: Measurement of bone mineral in vivo. An improved method. *Science* 142 (1963) 230
- GITMAN L, KAMHOLTZ T H and LEVINE J: Osteoporosis in the aged. Radiographic survey with clinical and biochemical correlations. *J Geront* 13 (1958), 43
- HARVALD B, KROGSGAARD A R and LÖF P: Calcium deficiency following partial gastrectomy. *Acta med scand* 172 (1962) 497
- ISAKSSON B and ÖHLSÖN L: The theoretical phosphorus balance. *Metabolism* 16 (1967) 314
- and SJÖGREN B: A critical evaluation of the calcium balance technique. Variation of fecal output. *Metabolism* 16 (1967) 295
- LINDHOLM M and SJÖGREN B: Dermal calcium balance. *Metabolism* 16 (1967), 303
- JACOBSON M: X-ray spectrophotometry in vivo. *Amer J Roentgenol* 91 (1964), 202
- JONES D M A and REINE H C: Correspondence. *Brit J Radiol* 22 (1949), 549
- KEANE B E, SPIEGLER G and DAVIS R: Quantitative evaluation of bone mineral by a radiographic method. *Brit J Radiol* 32 (1959) 162
- KROKOWSKI E and STEINER D: Röntgenologische Bestimmung des Kalziumgehalts im menschlichen Skelett. *Med Klinik* 56 (1961) 2073
- NORDIN B E C and SMITH D A: Diagnostic procedures in disorders of calcium metabolism. J & A Churchill, London 1965
- OESER H and KROKOWSKI M: Röntgenstrahlen zur visuellen Knochenbiopsie zwecks Bestimmung des Mineralgehaltes. *Dtsch med Wschr* 86 (1961) 2431
- OMNELL K A: Quantitative roentgenologic studies on changes in mineral content of bone in vivo. *Acta radiol* (1957) Suppl No 148
- SCHMID J: Kalktherapie bei Osteoporose. *Schweiz med Wschr* (1963), 1815

SYNOVIAL LESIONS IN THE ADULT HIP JOINT IN RHEUMATOID ARTHRITIS

by

W J WESTON

HEPKE & TURNER (1942) published their paper 'Obturator sign as earliest roentgenographic sign in diagnosis of septic arthritis and tuberculosis of the hip joint'. This was seen as a swelling of obturator internus on the lateral wall of the pelvis in the *m p* view.

In 1953, DREY reported synovitis of the hip joint producing swelling of the gluteus minimus, the most medial of the gluteal muscles lying above and lateral to the joint, and of the ilio-psoas just above its insertion into lesser trochanter, below and medial to the joint.

KELLOGG (1963) stated that 'the clinical diagnosis of early hip joint involvement in rheumatoid arthritis is difficult, because pain in the leg is so easily attributed to the more obvious concurrent disease of the knees, and small effusions in the hip are not readily demonstrated'. The signs of cartilage loss and the wedge shaped appearance of the superior part of the joint space are well known signs of rheumatoid involvement of the hip.

BERENS (1963) drew attention to the soft tissue signs in the early stage of hip joint lesions in rheumatoid arthritis such as capsular swelling or synovial

Submitted for publication 16 June 1969

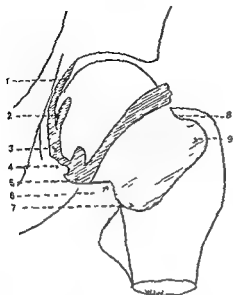


Fig 1 Line diagram of post mortem arthrogram of hip following injection of 12 ml of barium sulphate suspension 1—recessus capitis, 2—ligamentum teres 3—acetabular recess, 4—ligamentum transversum, 5—inferior recess, 6 and 8—zona orbicularis, 7 and 9—recessus colli



Fig 2 Post mortem arthrogram using 25 ml of barium sulphate suspension. The inferior recess is well seen caudal to the femoral neck.

SYNOVIAL LESIONS IN THE ADULT HIP JOINT IN RHEUMATOID ARTHRITIS

by

W J WESTON

HEFKE & TURNER (1942) published their paper 'Obturator sign as earliest roentgenographic sign in diagnosis of septic arthritis and tuberculosis of the hip joint'. This was seen as a swelling of obturator internus on the lateral wall of the pelvis in the *ap* view.

In 1953, DREY reported synovitis of the hip joint producing swelling of the gluteus minimus, the most medial of the gluteal muscles lying above and lateral to the joint, and of the ilio-psoas just above its insertion into lesser trochanter, below and medial to the joint.

KELLOGGREN (1963) stated that the clinical diagnosis of early hip joint involvement in rheumatoid arthritis is difficult, because pain in the leg is so easily attributed to the more obvious concurrent disease of the knees, and small effusions in the hip are not readily demonstrated. The signs of cartilage loss and the wedge shaped appearance of the superior part of the joint space are well known signs of rheumatoid involvement of the hip.

BERENS (1963) drew attention to the soft tissue signs in the early stage of hip joint lesions in rheumatoid arthritis such as capsular swelling or synovial

Submitted for publication 16 June 1969



Fig. 5 Ap and axial roentgenograms in a third case of active rheumatoid arthritis. The synovial mass (es) is well seen caudal to the femoral neck in the axial view (arrows).

can be demonstrated radiographically when the soft tissues are cleared from the overlying bone.

Arthrographic anatomy of the adult hip. Arthrography of the hip joint performed in the cadaver demonstrated the normal appearance of the synovial membrane about the hip joint.

The average hip at post mortem will take about 12 ml of contrast medium. In one case the hip was over distended with 25 ml contrast medium. The impression of the orbicular ligament was well seen, as was the bulging synovial membrane on the caudal aspect of the neck medial to the orbicular ligament (Fig. 2).

The contrast medium was seen in the arthrogram as a thin layer about the femoral head. The ligamentum teres may be seen on the medial aspect of the head with contrast medium each side of it. The ligamentum transversum spans the cotyloid notch leaving an indentation on the contrast medium below the ligamentum teres.

The circular orbicular ligament produces a waist above and below the femoral neck. On the under surface of the neck the inferior articular recess is seen medially and the recessus colli is seen laterally above and below the femoral neck. The supra articular recess lies above the limbus (LINDSTROM 1952, FLICHER 1952).



Fig 3 Arthrograms in a case of active rheumatoid arthritis. Distended capsular recess caudal to the femoral neck associated with nodular filling defects of the hypertrophic synovial membrane.

involvement. SOSMAN (1963) also mentioned the capsular contour as seen against the fat pad above the hip, i.e. between the superior acetabular margin and the greater trochanter, and especially well seen in children the fat and muscle line which is visible inferiorly.

REICHMANN (1967) stated that it is impossible to identify the upper capsular contour with certainty.

It is my belief that in rheumatoid arthritis the distended joint capsule caudal to the joint, produced by the synovial mass lesion in the axial view of the hip



Fig 4 Arthrograms in a further case of active rheumatoid arthritis. Distended capsular recess caudal to the femoral neck.

REFERENCES

- BERENS D L Hips *In* Radiological aspects of rheumatoid arthritis International Congress Series No 61, p 307 Excerpta Medica Foundation, Amsterdam 1963
- BULLOCK J E Arthrography of the adult hip joint *J Bone Jt Surg* 47A (1964), 853
- DREY L A roentgenographic study of transitory synovitis of the hip joint *Radiology* 60 (1953), 588
- FISCHER F K Joint injuries — Arthrography *In* Roentgen diagnosis. Volume 2, p 1218 Edited by H R Schunz, W E Baensch, E Friedl and E Uehlinger Grune and Stratton New York 1952
- HEI
- KE
- tional Congress Series No 61, p 301 Excerpta Medica Foundation Amsterdam 1963
- LEWIS R W The hip *In* The joints of the extremities A radiographic study Charles C. Thomas Springfield Illinois 1955
- LINDBLOM K Arthrography *In* Modern trends in diagnostic radiology Second series, p 251 Butterworths, London 1953
- Arthrography *J Fac Radiol (Lond)* 3 (1952), 151
- REICHMAN S Roentgenologic soft tissue appearances in hip joint disease *Acta radiol Diagnosis* 6 (1967), 167
- SOSMAN J L Hips *In* Radiological aspects of rheumatoid arthritis International Congress Series, No 61, p 307 Excerpta Medica Foundation, Amsterdam 1963
- WESTON W J Positive contrast arthrography in rheumatoid arthritis *Aust Radiol* 12 (1968) 141

Study of the normal arthrogram makes one realise that the assessment of the synovial changes above the hip are not easy. The synovial swelling in rheumatoid arthritis produced a mass lesion on the undersurface of the neck. Less easily seen is the capsular swelling above the neck, as described by BERENS.

The soft tissue mass lesion in the standard n.p. film can be hidden by the overlying ischio-pubic ramus. The overlying bones are cleared in the axial view, in which the caudal soft tissue changes are seen to the best advantage.

Arthrogams in two cases with rheumatoid arthritis of the hips are also presented. The widest portion of the joint recesses may be seen caudal to the femoral neck. Rheumatoid arthritis produces an enlargement of the capsular recesses, as has been demonstrated by arthrography (WESTON 1968). The hypertrophic synovial membrane with its nodular filling defects is demonstrated in the arthrograms (Figs 3 and 4).

No mention has previously been made that the synovial thickening at the hip may be seen as a soft tissue mass on conventional films. It has a well defined caudal margin. It is best demonstrated in the axial view where the swelling is cleared from the ischio-pubic ramus (Fig 5).

The soft tissues cephalic to the femoral neck are difficult to assess as there is considerable variation in this area depending on the projection. REICHMAN (1967) considers that the appearances vary also with body build and with the state of muscular contraction.

SUMMARY

Well defined synovial mass lesions on the caudal aspect of the femoral neck due to rheumatoid arthritis could be demonstrated in the axial view during conventional radiography of the hip.

ZUSAMMENFASSUNG

Synovialmassen infolge Arthritis deformans am kaudalen Abschnitt des Schenkelhalses wurden in der Axialprojektion während gewöhnlicher Radiographie der Hüfte gut erkennbar.

RÉSUMÉ

L'incidence axiale dans la radiographie simple de la hanche a permis de mettre en évidence des lésions bien délimitées de la synoviale, situées sur la face inférieure du col fémoral et dues à la polyarthrite rhumatoïde.

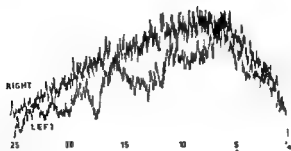


Fig 1 Renography in a patient, aged 48 with uterine carcinoma and pelvic metastases. The right renogram is normal. The left renogram shows a normal ascending limb but in the excretory or clearing phase the curve has a wavy form.

hippuratesodium. The animals lay supine and collimators were placed under manual control through the abdominal cavity at the sites of the kidneys. After intravenous injection of 40 μ Ci of the isotope, the other ureter was clamped as the curve began to slope downwards. The right ureter and kidney were left free and served as controls.

Results

A rapid rise in the curve occurred when the clamping was made at the uretero-pelvic junction, and there was a rapid fall when the clamping was released. The short wave-form of the curve (Fig 3a) could thus be produced experimentally.

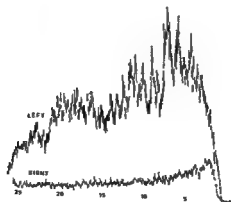


Fig 2 Renography in a patient, aged 44, with uterine carcinoma and pelvic metastases. The right renogram indicates poor function of the kidney. The curve for the left kidney indicates normal function but the descending limb has a wavy form.

EXPERIMENTAL ISOTOPE RENOGRAPHY AS A MEANS OF LOCALIZING URETERIC OBSTRUCTION

by

ILMARI LINDGREN and PEKKA MAKELA

Clinical isotope renography may show a normal curve for one kidney but a more sloping wave form of the descending limb of the other kidney. This phenomenon has earlier been described in the literature although its significance may have been neglected (WINTER 1963, ZUM WINKEL 1964) or attributed to arterial hypertension with a renal lesion (WAL et coll 1966). The present authors, having encountered about a dozen patients with a regular short wave form from one kidney, and some kind of ureteric obstruction (Figs 1 and 2), considered that this phenomenon might be due to a relative or valve-like obstruction of the other ureter. Experiments were therefore performed in dogs, whose ureters were closed at different levels for varying lengths of time.

Material and Methods Six adult mongrel dogs weighing 20 to 25 kg were operated on under pentobarbitone anaesthesia (nembutal) and the left ureter was clamped atraumatically for varying lengths of time during renography. The occlusions were placed (1) just below the renal pelvis, (2) at the middle of the ureter, and (3) at the ureteric orifice. Renography was performed with ^{131}I -iodo-

Submitted for publication 25 June 1969. This work was financially supported by the Sigrid Juselius Foundation.

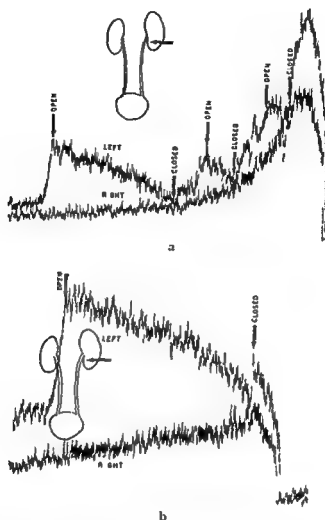


Fig 3 Renography in a dog a) Clamping was made at the ureteropelvic junction b) The curve for the left kidney shows the effect of clamping during a longer period of time (The paper speed was the same as in figs 1 2 and 4)

When the clamping was maintained for a longer period, with injection of a second isotope dose, the curve continued to rise (Fig 3b) but it fell quickly when the clamping was released. Clamping of the middle part of the ureter produced no immediate effect and the wave of the curve was much longer (Fig 4a). A further isotope injection without compression of the ureter caused no such effect (Fig 4b), indicating that no damage had occurred in the kidney which had been affected by ureteric obstruction for 10 minutes. Finally, when the ureter was compressed at the ureteropelvic junction, no effect on the shape of the curve could be obtained (Fig 5). The curves of the right kidney were also normal in shape in all the experiments.

DOUBLE CONTRAST CYSTOGRAPHY

A new contrast medium and a simplified technique

by

J TH JENSEN

Double contrast cystography has gradually found its place and justification in diagnostic radiology. Certain authors (DIETHELM et coll 1964, JOHANNESEN 1965), have however, expressed some dissatisfaction with the mucosal coating of the positive contrast media and have pointed out the necessity of refining the technique. Several available contrast media have been compared, the best proving to be of approximately the same quality. The procedure appears to be time-consuming, and owing to the numerous exposures — expensive and perhaps exposes the gonads to an unnecessarily high radiation dose (BARTLEY & HELANDER 1960, BETOLLIÈRES et coll 1963, DIETHELM et coll 1964, POCHACZEWSKI & GRABSTADT 1964).

The object of the present study was twofold: to find a positive contrast medium adhering better to the mucosa than those previously available and to simplify and, if possible, improve the technique.

Material and methods The material comprised patients referred for cystography and those with prostatic hypertrophy who were to undergo catheterization or instrumentation of the urinary tract. Such patients, elderly, often immobile,

From the Roentgendiagnostic Department (Director Th. Rasmussen), Central Hospital, Hjørring, Denmark. Submitted for publication 17 July 1969.

Comments ZUM WINKEL (1964) has described the curve from experimental ureteric obstruction corresponding to the present experiment in Fig 3b This figure indicates that a valve-like ureteric obstruction produces a curve of wavy form in the renogram. In clinical renography, this shape of the curve could be due to a stone or any other calcifications in the renal pelvis It might be explained by a rise in pressure in the ureter through the build-up in the volume of urine until it reached a point where it caused a relaxation of the wall and the urine to flow out, with a resultant decrease in the curve of the renogram This may possibly, even in relative stasis, be caused by a tumour, for example

This study furthermore has indicated that it may be possible to localize the height of ureteric obstructions from the renogram curve

SUMMARY

Experiments in isotope renography were performed in dogs whose ureters were closed at various levels for different lengths of time It seems possible to determine the level of ureteric obstruction clinically from renograms obtained in this manner

ZUSAMMENFASSUNG

Experimente an Hunden wurden mit Isotopenrenographie während Blockierung der Ureteren an verschiedenen Höhen und zu wechselnden Zeitintervallen vorgenommen Mit solchen Renogrammen scheint es möglich zu sein die Höhe der Ureterobstruktion klinisch zu bestimmen

RÉSUMÉ

Les auteurs ont étudié expérimentalement sur des chiens la néphrographie isotopique après ligature des uretères à différents niveaux et pendant de durées variables Il paraît possible de déterminer d'après le néphrogramme le niveau de l'obstruction urétérale

REFERENCES

- WAX S H, AL-HUSSAINI M and McDONALD D F Effect of angiotensin on the ^{131}I sodium ortho iodohippurate renogram *Invest Urol* 3 (1966) 520
 ZUM WINKEL K Nierendiagnostik mit Radioisotopen Georg Thieme Verlag Stuttgart 1964
 WINTER C C Radioisotope renography Williams & Wilkins Baltimore 1963

DOUBLE CONTRAST CYSTOGRAPHY

A new contrast medium and a simplified technique

by

J TH JENSEN

Double contrast cystography has gradually found its place and justification in diagnostic radiology. Certain authors (DIETHELM *et coll* 1964, JORANESSEV 1965), have however, expressed some dissatisfaction with the mucosal coating of the positive contrast media and have pointed out the necessity of refining the technique. Several available contrast media have been compared, the best proving to be of approximately the same quality. The procedure appears to be time-consuming, and owing to the numerous exposures is expensive and perhaps exposes the gonads to an unnecessarily high radiation dose (BARTLEY & HELANDER 1960, BETOLLIÈRES *et coll.* 1963, DIETHELM *et coll* 1964, POCHACZEWSKI & GRABSTAD 1964).

The object of the present study was twofold: to find a positive contrast medium adhering better to the mucosa than those previously available and to simplify and, if possible, improve the technique.

Material and methods. The material comprised patients referred for cystography and those with prostatic hypertrophy who were to undergo catheterization or instrumentation of the urinary tract. Such patients, elderly, often immobile,

From the Roentgendiagnostic Department (Director Th. Rasmussen), Central Hospital, Hjørring, Denmark. Submitted for publication 17 July 1969.

and with cystitis, were preferred for assessing the procedure under the most difficult conditions, this made the greatest demands on the coating characteristics of the positive contrast medium

Many authors (BARTLEY & HELANDER 1960, BLAKEMORE et coll 1958, DIETHELM et coll 1964, DOYLE 1961, JENSEN & HOLM 1965, JOHANNESSEN 1965, LUKE 1964, POCHACZEWSKY & GRABSTALD 1964, SHAWDOY et coll 1965, STAUFER et coll 1956) have stated that carbon dioxide is the best negative contrast medium, especially as it involves only a slight risk of gas embolism, it was the only negative contrast medium used in the present study

The positive contrast media employed in the first examinations (BARTLEY & HELANDER 1960, BETOULIERES et coll 1963, DIETHELM et coll 1964, DOYLE 1961, HARBOE KRISTENSEN 1964, JENSEN & HOLM 1965, JOHANNESSEN 1965, LUKE 1964, MORALES & ROMANUS 1952, POCHACZEWSKY & GRABSTALD 1964, SHAWDOY et coll 1965 and WALDEN 1944) were Propylidone, SH 617 L, Steripaque + Edifas B 50 in a mixture (Edifas is a preparation of sodium carboxymethyl cellulose manufactured by ICI), and barium sulphate + Edifas B 50 mixed in various ratios and in quantities varying from 5 to 20 ml These will be considered together as the ordinary contrast media

The injection of contrast medium was sometimes preceded by irrigation of the bladder with isotonic glucose or isotonic sodium chloride, and occasionally with undiluted Edifas B 50 The amount of fluid was always 100 ml

The new contrast medium consisted of barium sulphate 500 g, Edifas B 50 24 g and distilled water ad 1 000 g and was dispensed sterilized in tubes of 7 ml The examinations with this contrast medium were not preceded by bladder irrigation

The bladder was emptied by catheterization and sometimes irrigated before an ordinary contrast medium followed by 50 ml carbon dioxide was injected The patient was then rotated once laterally, a further 150 ml carbon dioxide was injected and the patient was rotated again and tilted supine with the head down The following projections were obtained under fluoroscopic control (1) a p supine, (2) patient turned 45° to the right, (3) 45° to the left and (4) to the lateral decubitus position With the patient tilted 15° head down from the supine position, films were exposed (5) a p with the tube tilted 40° cranially and (6) a p with the tube tilted 10° caudally All the films were obtained with a vertical beam This technique will be referred to as the known technique

The new technique ■ a follows The patient voids before the examination, a catheter is passed, the bladder is emptied, and the residual urine is, if necessary measured and 7 ml contrast medium followed by 50 ml carbon dioxide are injected The patient is now rotated laterally, a whole turn with brief stops in the



Fig 1 Male aged 70 years with hypertrophy of the prostate a) Prone position, horizontal beam b) Right decubitus position horizontal beam c) Left decubitus position horizontal beam d) Prone position vertical beam (The illustrations represent examinations with the new contrast medium and technique)

right and left lateral decubitus and prone positions, a further 150 ml carbon dioxide is injected (On rare cases, with a large bladder volume possibly a larger dose) The four films obtained consist of projections with a horizontal beam with the patient prone, in the right and left lateral decubitus positions, and with a vertical beam and the patient prone (cf Fig 1) These projections have been described in the literature (BARTLEY & HELANDER 1960, DOYLE 1961 and 1963, POCHACZEWSKY & GRABSTAD and WALLDEN 1941), but an attempt has been made in the present material to reduce the number of exposures to a minimum without compromising the diagnostic reliability.

It may be mentioned that the new contrast medium is also admirably suited for retrograde urethrography

Table 1

Quality of films assessed in relation to the contrast medium and technique Of the 7 patients of the 'medium' group examined by the new technique with the new contrast medium 4 had a good deal of urine in the bladder, and another set of films was incorrectly exposed

	Good	Medium	Poor
Ordinary contrast medium			
Ordinary technique	5	17	16
Ordinary contrast medium			
New technique	4	5	0
New contrast medium			
New technique	58	7	0

Table 2

Adhesion of contrast media to bladder mucosa assessed in relation to technique Of the 9 patients in the 'medium' group examined by the new technique with new contrast medium, 6 had too much urine in the bladder This also applies to one patient of the 'poor' group examined by the same technique and with the same contrast medium

	Good	Medium	Poor
Ordinary contrast medium			
Ordinary technique	4	4	30
Ordinary contrast medium			
New technique	3	5	1
New contrast medium			
New technique	54	9	2

Double contrast cystography was performed in a few instances in continuation of retrograde urethrography with introduction of the contrast medium as well as the CO₂ through Knutson's apparatus, i.e. without catheterization. However, this is not recommended as during the long examination the urine flowing into the bladder reduces the quality of the films — further evidence that the quality is better the less urine there is in the bladder, i.e. the quicker the examination is performed. This is one of the reasons why the author has tried to reduce the number of the exposures to a minimum and to use only simple adjustments of the tube.

The exposure in the prone position with a horizontal beam is necessary to

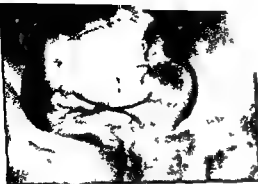


Fig 2 Male aged 74 years with carcinoma of the left side of the bladder. Right decubitus position horizontal beam. The sequelae of transvesical prostatectomy performed 9 years previously. (The illustration represents an examination with the new contrast medium and technique.)

demonstrate the base of the bladder which is not always defined in the lateral decubitus position (DOYLE 1963).

On occasions the patient was not rotated until all the CO₂ had been injected. The contrast medium however then became deposited as a girdle around the equator.

The material comprised 112 examinations distributed over 105 patients ranging in age from 5 to 87 years with 30 examinations in females and 82 in males. Forty-five examinations were in patients under 60 years of age and 67 in patients over 60. 47 examinations were performed with the ordinary contrast medium and 65 with the new medium, 38 were by the ordinary technique and 74 by the new technique.

In reviewing the films an attempt was made to sort the material by the quality of the exposures and by the coating property of the positive contrast medium. This assessment is purely subjective and consequently carries some inaccuracy. The results of these assessments are given in Tables 1 and 2.

The tabulated results indicate that the new medium and technique produce improved results, including better coating of the bladder wall.

Results

The material was divided into the following three groups:

- Group I 38 examinations with an ordinary contrast medium and technique.
- Group II 9 examinations with an ordinary medium and the new technique.
- Group III 65 examinations with the new medium and technique.

The diagnoses by double contrast cystography and by urography and surgical procedures, i.e. cystoscopy and operation, were compared. Urography was not

Table 1

Quality of films assessed in relation to the contrast medium and technique. Of the 7 patients of the 'medium' group examined by the new technique with the new contrast medium 4 had a good deal of urine in the bladder, and another set of films was incorrectly exposed

	Good	Medium	Poor
Ordinary contrast medium			
Ordinary technique	5	17	16
Ordinary contrast medium			
New technique	4	5	0
New contrast medium			
New technique	58	7	■

Table 2

Adhesion of contrast media to bladder mucosa assessed in relation to technique. Of the 9 patients in the 'medium' group examined by the new technique with new contrast medium, 6 had too much urine in the bladder. This also applies to one patient of the 'poor' group examined by the same technique and with the same contrast medium

	Good	Medium	Poor
Ordinary contrast medium			
Ordinary technique	4	4	30
Ordinary contrast medium			
New technique	3	5	1
New contrast medium			
New technique	54	9	2

Double contrast cystography was performed in a few instances in continuation of retrograde urethrography with introduction of the contrast medium as well as the CO₂ through Knutson's apparatus, i.e. without catheterization. However, this is not recommended as during the long examination the urine flowing into the bladder reduces the quality of the films — further evidence that the quality is better the less urine there is in the bladder, i.e. the quicker the examination is performed. This is one of the reasons why the author has tried to reduce the number of the exposures to a minimum and to use only simple adjustments of the tube.

The exposure in the prone position with a horizontal beam is necessary to



Fig 2 Male, aged 74 years, with carcinoma of the left side of the bladder. Right decubitus position, horizontal beam. The sequelae of transvesical prostatectomy performed 9 years previously (The illustration represents an examination with the new contrast medium and technique)

demonstrate the base of the bladder which is not always defined in the lateral decubitus position (DOYLE 1963)

On occasions the patient was not rotated until all the CO_2 had been injected. The contrast medium however then became deposited as a girdle around the 'equator'

The material comprised 112 examinations distributed over 105 patients ranging in age from 5 to 87 years with 30 examinations in females and 82 in males. Forty-five examinations were in patients under 60 years of age and 67 in patients over 60, 47 examinations were performed with the ordinary contrast medium and 65 with the new medium, 38 were by the ordinary technique and 74 by the new technique

In reviewing the films an attempt was made to sort the material by the quality of the exposures and by the coating property of the positive contrast medium. This assessment is purely subjective and consequently carries some inaccuracy. The results of these assessments are given in Tables 1 and 2

The tabulated results indicate that the new medium and technique produce improved results, including better coating of the bladder wall

Results

The material was divided into the following three groups

- Group I 38 examinations with an ordinary contrast medium and technique
- Group II 9 examinations with an ordinary medium and the new technique
- Group III 65 examinations with the new medium and technique

The diagnoses by double contrast cystography and by urography and surgical procedures, i.e. cystoscopy and operation, were compared. Urography was not

Table 1

Quality of films assessed in relation to the contrast medium and technique Of the 7 patients of the 'medium' group examined by the new technique with the new contrast medium 4 had a good deal of urine in the bladder, and 1 another set of films was incorrectly exposed

	Good	Medium	Poor
Ordinary contrast medium			
Ordinary technique	5	17	16
Ordinary contrast medium			
New technique	4	5	0
New contrast medium			
New technique	58	7	0

Table 2

Adhesion of contrast media to bladder mucosa assessed in relation to technique Of the 9 patients in the 'medium' group examined by the new technique with new contrast medium, 6 had too much urine in the bladder This also applies to one patient of the 'poor' group examined by the same technique and with the same contrast medium

	Good	Medium	Poor
Ordinary contrast medium			
Ordinary technique	4	4	30
Ordinary contrast medium			
New technique	3	5	1
New contrast medium			
New technique	54	9	2

Double contrast cystography was performed in a few instances in continuation of retrograde urethrography with introduction of the contrast medium as well as the CO₂ through Knutson's apparatus, i.e. without catheterization. However, this is not recommended as during the long examination the urine flowing into the bladder reduces the quality of the films — further evidence that the quality is better the less urine there is in the bladder, i.e. the quicker the examination is performed. This is one of the reasons why the author has tried to reduce the number of the exposures to a minimum and to use only simple adjustments of the tube.

The exposure in the prone position with a horizontal beam is necessary to

and 23 patients in group III. The hypertrophy had escaped detection at urography in 4 patients but was confirmed by cystoscopy in all but one, and in this latter by examination of the rectum.

Other diagnoses were diverticula of the bladder (in patients with urethral stricture), cystocele (in genital prolapse), and patent internal urethral orifice. This latter finding was made in patients who had undergone operations on the prostate. There was no diagnostic disagreement in any of these patients, but the examinations in group III revealed the changes most distinctly.

Conclusion

The investigation would appear to confirm the diagnostic value of double contrast cystography in bladder diseases, in particular its superiority to conventional urography. The normal findings in the present material were confirmed by cystoscopy. All tumours were demonstrated, and in 2 patients double contrast cystography proved superior to cystoscopy, in one of these severe bleeding obscured the cystoscopy and in the other the topography of the tumour was better established by double contrast cystography. The extent of bladder invasion by extrinsic malignancy could also be assessed.

Cystoscopy appears to be preferable to double contrast cystography in the diagnosis of cystitis and vesical calculi.

There seems to be good agreement between double contrast cystography and the surgical methods of diagnosis in hypertrophy of the prostate, the former is superior to ordinary urography.

The new contrast medium appears to adhere better to the mucosa and thus produce more acceptable films than the usual media. In addition, the introduction of a new, simplified diagnostic method demands fewer exposures than previously without any reduction in diagnostic reliability.

SUMMARY

A new contrast medium and a simplified diagnostic technique for double contrast cystography are described. The results are compared with those obtained by conventional urography and cystoscopy. The new method is found to be superior to the latter in the diagnosis of prostatic hypertrophy and in the demonstration of bladder tumours. The new contrast medium is found to be superior to the usual media in the production of acceptable films. The introduction of a new, simplified diagnostic method demands fewer exposures than previously without any reduction in diagnostic reliability.

ZUSAMMENFASSUNG

Beschreibung eines neuen Kontrastmittels und einer vereinfachten Prozedur für die Doppelkontrastdarstellung der Harnblase. Die Resultate der neuen Methode werden besprochen und mit denen der alten Methode verglichen. Sie bestätigen den Wert der Doppelkontrastdarstellung der Harnblase besonders bei malignen Erkrankungen, bei denen die Bestimmung der Ausdehnung des Tumors sich besonders nützlich erwies.

performed in a few patients, *inter alia*, because of elevated serum creatinine. Cystoscopy or other surgical procedures were not carried out in 26 patients (11 in group I, 1 in group II and 14 in group III).

No abnormality was detected by double contrast cystography in 31 cases (10 of group I, 2 of group II and 19 of group III). Urography suggested mural infiltration in 1 patient of group III but this was not confirmed by double contrast cystography and conventional cystoscopy. Cystoscopy revealed trigonal cystitis in another patient of this group.

Vesical tumours were demonstrated by double contrast cystography in 18 patients of the three groups consisting of 2 in group I and 3 patients in group II. Urography in 3 of these 5 patients has suggested a vesical growth which was subsequently confirmed by cystoscopy. Double contrast cystography revealed perivesical malignant infiltration in 2 patients of group II while urography indicated no abnormality, operation revealed carcinoma of the prostate invading the surrounding structures.

Four out of 10 vesical growths in group III (cf Fig 2) had escaped detection at urography. The tumour in another patient had been masked at cystoscopy by bleeding. Cystoscopy in yet another patient had first disclosed one small tumour, double contrast cystography however revealed 3 larger papillomatous growths with marked infiltration of the bladder wall and this was later confirmed by repeat cystoscopy.

Double contrast cystography demonstrated an infiltrating tumour in 1 patient and biopsy indicated carcinoma of the urinary bladder. Subsequent operation disclosed marked cystitis, and was confirmed by further biopsy.

Three patients of group III had invasion of the bladder, in one from carcinoma of the sigmoid colon and in two from carcinoma of an ovary, the diagnoses were confirmed at operation or autopsy. Two of the patients had had a normal bladder at urography, while in the third patient urography had demonstrated compression of the right ureter.

Cystitis was disclosed by double contrast cystography in 10 patients, 7 of whom were in group I and 3 in group III, this was confirmed in 9 patients by cystoscopy. Cystoscopy also revealed cystitis in 5 patients from other parts of the material, which had not been demonstrated by double contrast cystography.

Vesical stones in two patients were confirmed by urography and cystoscopy. Double contrast cystography suggested calculi in another patient, these were confirmed by cystoscopy.

Hypertrophy of the prostate was diagnosed by double contrast cystography in 35 patients (cf Fig 1), sometimes co-existing with trabeculation of the bladder, diverticula and cystitis, and in 4 patients with malignancy (also listed in the group of tumours). The distribution was 10 patients in group I, 2 in group II

and 23 patients in group III. The hypertrophy had escaped detection at urography in 4 patients but was confirmed by cystoscopy in all but one, and in this latter by examination of the rectum.

Other diagnoses were diverticula of the bladder (in patients with urethral stricture), cystocoele (in genital prolapse), and patent internal urethral orifice. This latter finding was made in patients who had undergone operations on the prostate. There was no diagnostic disagreement in any of these patients, but the examinations in group III revealed the changes most distinctly.

Conclusion

The investigation would appear to confirm the diagnostic value of double contrast cystography in bladder diseases, in particular its superiority to conventional urography. The normal findings in the present material were confirmed by cystoscopy. All tumours were demonstrated, and in 2 patients double contrast cystography proved superior to cystoscopy, in one of these severe bleeding obscured the cystoscopy and in the other the topography of the tumour was better established by double contrast cystography. The extent of bladder invasion by extrinsic malignancy could also be assessed.

Cystoscopy appears to be preferable to double contrast cystography in the diagnosis of cystitis and vesical calculi.

There seems to be good agreement between double contrast cystography and the surgical methods of diagnosis in hypertrophy of the prostate, the former is superior to ordinary urography.

The new contrast medium appears to adhere better to the mucosa and thus produce more acceptable films than the usual media. In addition, the introduction of a new, simplified diagnostic method demands fewer exposures than previously without any reduction in diagnostic reliability.

SUMMARY

A new contrast medium and a simplified diagnostic technique for double contrast cystography are described. The results are discussed and compared with those previously obtained. The study confirms the value of double contrast cystography in bladder conditions especially in malignancy in which the demonstration of the extent of the growth is valuable.

ZUSAMMENFASSUNG

Beschreibung eines neuen Kontrastmittels und einer vereinfachten Prozedur für die Doppelkontrastdarstellung der Harnblase. Die Resultate der neuen Methode werden besprochen und mit denen der alten Methode verglichen. Sie bestätigen den Wert der Doppelkontrastdarstellung der Harnblase, besonders bei malignen Erkrankungen, bei denen die Bestimmung der Ausdehnung des Tumors sich besonders nützlich erwies.

performed in a few patients, inter alia, because of elevated serum creatinine. Cystoscopy or other surgical procedures were not carried out in 26 patients (11 in group I, 1 in group II and 14 in group III).

No abnormality was detected by double contrast cystography in 31 cases (10 of group I, 2 of group II and 19 of group III). Urography suggested mural infiltration in 1 patient of group III but this was not confirmed by double contrast cystography and conventional cystoscopy. Cystoscopy revealed trigonal cystitis in another patient of this group.

Vesical tumours were demonstrated by double contrast cystography in 18 patients of the three groups consisting of 2 in group I and 3 patients in group II. Urography in 3 of these 5 patients has suggested a vesical growth which was subsequently confirmed by cystoscopy. Double contrast cystography revealed perivesical malignant infiltration in 2 patients of group II while urography indicated no abnormality, operation revealed carcinoma of the prostate invading the surrounding structures.

Four out of 10 vesical growths in group III (cf. Fig. 2) had escaped detection at urography. The tumour in another patient had been masked at cystoscopy by bleeding. Cystoscopy in yet another patient had first disclosed one small tumour, double contrast cystography however revealed 3 larger papillomatous growths with marked infiltration of the bladder wall and this was later confirmed by repeat cystoscopy.

Double contrast cystography demonstrated an infiltrating tumour in 1 patient and biopsy indicated carcinoma of the urinary bladder. Subsequent operation disclosed marked cystitis, and was confirmed by further biopsy.

Three patients of group III had invasion of the bladder, in one from carcinoma of the sigmoid colon and in two from carcinoma of an ovary, the diagnoses were confirmed at operation or autopsy. Two of the patients had had a normal bladder at urography, while in the third patient urography had demonstrated compression of the right ureter.

Cystitis was disclosed by double contrast cystography in 10 patients, 7 of whom were in group I and 3 in group III, this was confirmed in 9 patients by cystoscopy. Cystoscopy also revealed cystitis in 5 patients from other parts of the material, which had not been demonstrated by double contrast cystography.

Vesical stones in two patients were confirmed by urography and cystoscopy. Double contrast cystography suggested calculi in another patient, these were confirmed by cystoscopy.

Hypertrophy of the prostate was diagnosed by double contrast cystography in 35 patients (cf. Fig. 1), sometimes co existing with trabeculation of the bladder, diverticula and cystitis, and in 4 patients with malignancy (also listed in the group of tumours). The distribution was 10 patients in group I, 2 in group II

and 23 patients in group III. The hypertrophy had escaped detection at urography in 4 patients but was confirmed by cystoscopy in all but one, and in this latter by examination of the rectum.

Other diagnoses were diverticula of the bladder (in patients with urethral stricture), cystocele (in genital prolapse), and patent internal urethral orifice. This latter finding was made in patients who had undergone operations on the prostate. There was no diagnostic disagreement in any of these patients, but the examinations in group III revealed the changes most distinctly.

Conclusion

The investigation would appear to confirm the diagnostic value of double contrast cystography in bladder diseases, in particular its superiority to conventional urography. The normal findings in the present material were confirmed by cystoscopy. All tumours were demonstrated, and in 2 patients double contrast cystography proved superior to cystoscopy, in one of these severe bleeding obscured the cystoscopy and in the other the topography of the tumour was better established by double contrast cystography. The extent of bladder invasion by extrinsic malignancy could also be assessed.

Cystoscopy appears to be preferable to double contrast cystography in the diagnosis of cystitis and vesical calculi.

There seems to be good agreement between double contrast cystography and the surgical methods of diagnosis in hypertrophy of the prostate, the former is superior to ordinary urography.

The new contrast medium appears to adhere better to the mucosa and thus produce more acceptable films than the usual media. In addition, the introduction of a new, simplified diagnostic method demands fewer exposures than previously without any reduction in diagnostic reliability.

SUMMARY

A new contrast medium and a simplified diagnostic technique for double contrast cystography are described. The results are discussed and compared with those previously obtained. The study confirms the value of double contrast cystography in bladder conditions, especially in malignancy in which the demonstration of the extent of the growth is valuable.

ZUSAMMENFASSUNG

Beschreibung eines neuen Kontrastmittels und einer vereinfachten Prozedur für die Doppelkontrastdarstellung der Harnblase. Die Resultate der neuen Methode werden besprochen und mit denen der alten Methode verglichen. Sie bestätigen den Wert der Doppelkontrastdarstellung der Harnblase besonders bei malignen Erkrankungen bei denen die Bestimmung der Ausdehnung des Tumors sich besonders nützlich erwies.

RÉSUMÉ

Presentation d'un nouveau moyen de contraste et d'une technique simplifiée pour la cystographie en double contraste L'auteur examine les résultats et les compare avec ceux de la méthode utilisée auparavant Cette étude confirme l'intérêt de la cystographie en double contraste dans les affections vésicales, en particulier dans les affections malignes où il est important de déterminer l'étendue de la tumeur

REFERENCES

- BARTLEY O and HELANDER C G Double contrast cystography in tumors of the urinary bladder *Acta radiol* 54 (1960), 161
- BETOULIERES P, TRUG E, BADOSA J et coll La cystographie a double contraste *J Radiol Electrol* 44 (1963), 669
- BLAEMORE W S, MURPHY J J, PENDERGRASS H P and GREENING R R Carbon dioxide as contrast medium in roentgenography *J Amer med Ass* 167 (1958), 310
- DIETHELM L, RAPP W J, VITA G und ZEITLER E Kontrastmittelwahl und Möglichkeiten bei Doppelkontrastdarstellung der Harnblase *Fortschr Röntgenstr* 100 (1964), 727
- DOYLE F H Cystography in bladder tumours *Brit J Radiol* 34 (1961), 201
- Bladder cancer, double contrast cystography and a bladder analogue *Brit J Radiol* 36 (1963), 306
- HARBOE KRISTENSEN H Kontrastvædske (In Danish) *Farm Tid* 74 (1964), 449
- JENSEN J og HOLM H H Dobbeltkontrastcystografi (In Danish) *Ugeskr Læg* 127 (1965), 685
- JOHANNESSEN E Pneumocystografi (In Danish) *Dan med Bull* 12 (1965) 193
- LUKE H A Tumours of the bladder, radiological aspects *J Coll Radiol Aust* 8 (1964), 198
- MORALES O and ROMANUS R Urethrography in the male with a highly, viscous, water-soluble contrast medium, Umbradil viscous U *Acta radiol* (1952) Suppl No 95
- POCHACZEWSKY R and GRABSTAD H Double contrast barium cystography utilizing carbon dioxide *Amer J Roentgenol* 92 (1964), 365
- SHAWDON H H, DOYLE F H and SHACKMAN R Double contrast cystography applied to the diagnosis of tumours in bladder diverticula *Brit J Urol* 37 (1965), 536
- STAUFFER H M, DURANT F M and OPPENHEIMER M J Gas embolism *Radiology* 66 (1956), 686
- WALLDEN L On the diagnosis of spacerestricting processes in the small pelvis *Acta radiol* 25 (1944), 856

NON-FILLING OF THE VENTRICULAR SYSTEM IN ENCEPHALOGRAPHY

by

S HOLM MØLLER

Failure of the ventricles to fill in encephalography has been reported with varying frequency in the literature. Special attention has been focused on the extent to which the non-filling may have been due to the presence of an expanding intracranial lesion (Table 1).

LINDGREN (1949) published 152 cases subjected to encephalography, including ten in which the ventricular system failed to fill and in which no tumour was demonstrated. In four of the ten cases, cisternal puncture had been performed the day before. The clinical signs definitely indicated syringomyelia in one, and stenosis of the aqueduct of inflammatory origin in another case, in the remaining four cases, no explanation of the non-filling could be given.

DAVIDOFF & DYKE (1951) in a series of 1 056 cases observed non-filling in 7.3%, and tumours were present in 41% of these, in encephalography performed under general anaesthesia, non filling occurred in 12.7%. FALK (1953) published 1 841 cases which had undergone encephalography. The ventricles failed to fill in 90 cases (5%), including 24 (or 26.7%) with tumours, supratentorial in eight and infratentorial in sixteen of the cases. In addition,

Table 1

Survey of previous analyses of non filling of the ventricular system during encephalography

Author and year	Number of encephalographies	Non filling		Expanding intracranial lesion	
		Number	Per cent	Number	Per cent
LINDGREN (1949)	152	10	6.6	11	0
DAVIDOFF & DYKE (1951)	1 056	78	7.3	32	4.1
FALK (1953)	1 841	90	5	24	26.7
SCHULEMAN (1953)	572	133	23.3	6 (13)*	4.5 (9.7)*
SCHENBERG & YAIR (1955)	2 641	95**	3.6	34	48.5
RUGGIERO (1957)	670	47	7	23	48.9

* A tumour was diagnosed in six cases and was thought probable in a further seven cases

** Seventy of these were later studied by arteriography, ventriculography or repeat encephalography

stenosis of the aqueduct was present in three cases and confirmed arachnoiditis in four. Non-filling was in sixteen cases thought to be due to adhesions and fibrosis caused by preceding meningitis, subarachnoid haemorrhage, or birth trauma.

The survey published by SCHULEMAN (1953) covered the 5-year period 1944—1949. A tumour was diagnosed in six and thought probable in a further seven out of 133 cases without ventricular filling. SCHENBERG & YAIR (1955) observed non-filling in 95 out of 2 641 cases examined with encephalography, including 30 in which the air entered the subdural space. The examination was extended by arteriography, ventriculography or repeat encephalography in seventy of the ninety-five cases. A tumour was disclosed in thirty-four (48.5%) and congenital lesions obstructing the aqueduct in five cases.

RUGGIERO (1957) analysed 670 encephalographies from the period 1952—1955. Absence of ventricular filling was recorded in 47 cases (7%). Of these, twenty-three cases (48.9%) revealed expanding intracranial lesions: supratentorial in six, infratentorial in fourteen and multiple lesions in three cases. Stenosis of the aqueduct was present in four cases. The air entered the subdural space in two cases. Finally, VESTERDAL *et coll.* (1954) had 6 cases of non-filling in a series of 215 encephalographies from a paediatric department. No tumours were observed.

Of these authors, LINDGREN, as well as FALK and RUGGIERO, employed the method of LINDGREN (1949, 1950, 1954). SCHENBERG & YAIR did not give

their technique and the examinations in the other series mentioned were not performed in the form of controlled fractionated encephalography

Material and Methods Our series consists of 6915 encephalographies in the 10 year period 1958—1968, 600 of which were performed under general anaesthesia. A relatively large number produced normal findings, i.e. 2853 or about 40 %. We consider encephalography not only a valuable but also a relatively lenient method of examination and practically all cases with convulsive seizures are subjected to encephalography. It may be mentioned however that ventriculography is performed first if the presence of a tumour of the posterior cranial fossa is considered probable. During the above mentioned period, ventriculography was carried out in 1625 cases.

Out of the 6915 encephalographies absence of ventricular filling was noted in 95 cases (1.4 %). Fractionated encephalography by the method of LINDQREN (1949) is generally employed. In nine of the ninety five cases fractionation was not used, however, these were cases of children under 7 years of age. The examination is nearly always performed without anaesthesia but general anaesthesia was used in fifteen of the ninety five cases without filling, viz. all patients under the age of 15 years and in two aged 17 and 26 years. Oxygen was used for the injection.

The age distribution of the ninety five cases (Table 2) was fairly even, with a maximum between the ages 40 and 50 years. Two patients were under 12 months old but none was over 70 years. The numbers of males and females were almost equal.

Results

Fourteen of the ninety five cases had expanding intracranial lesions (14.7 %), these were supratentorial in four (three extracerebral and one intracerebral), infratentorial in nine (five intracerebellar and four extracerebellar) and in one case consisted of metastases to the cerebrum and cerebellum. There were five women between 18 and 64 years of age and nine men aged between 20 and 64 years.

Varying amounts of air entered the subdural space in thirteen cases, three of these had been subjected to lumbar puncture shortly before and one had undergone craniotomy with inspection of the posterior fossa a week before encephalography. Neoplasms were absent in these cases. In the remaining sixty eight cases no expanding intracranial lesions were demonstrated. Twenty five had had epileptic seizures but check up examinations failed to reveal any cerebral growth.

Repeat encephalography was performed in 46 cases. Non filling still occurred

Table 1

Survey of previous analyses of non filling of the ventricular system during encephalography

Author and year	Number of encephalographies	Non filling		Expanding intracranial lesion	
		Number	Per cent	Number	Per cent
LINDGREN (1949)	152	10	6.6	0	0
DAVIDOFF & DYKE (1951)	1 056	78	7.3	32	4.1
FALK (1953)	1 811	90	5	24	26.7
SCHULEMAN (1953)	572	133	23.3	6 (13)*	4.5 (9.7)*
SCHEINBERG & YAIR (1955)	2 641	95**	3.6	34	48.5
RUGGIERO (1957)	670	47	7	23	48.9

* A tumour was diagnosed in six cases and was thought probable in a further seven cases

** Seventy of these were later studied by arteriography, ventriculography or repeat encephalography

stenosis of the aqueduct was present in three cases and confirmed arachnoiditis in four. Non filling was in sixteen cases thought to be due to adhesions and fibrosis caused by preceding meningitis, subarachnoid haemorrhage, or birth trauma.

The survey published by SCHULEMAN (1953) covered the 5 year period 1944—1949. A tumour was diagnosed in six and thought probable in a further seven out of 133 cases without ventricular filling. SCHEINBERG & YAIR (1955) observed non-filling in 95 out of 2 641 cases examined with encephalography, including 30 in which the air entered the subdural space. The examination was extended by arteriography, ventriculography or repeat encephalography in seventy of the ninety-five cases. A tumour was disclosed in thirty four (48.5%) and congenital lesions obstructing the aqueduct in five cases.

RUGGIERO (1957) analysed 670 encephalographies from the period 1952—1955. Absence of ventricular filling was recorded in 47 cases (7%). Of these, twenty three cases (48.9%) revealed expanding intracranial lesions: supratentorial in six, infratentorial in fourteen and multiple lesions in three cases. Stenosis of the aqueduct was present in four cases. The air entered the subdural space in two cases. Finally, VESTERDAL *et coll.* (1954) had 6 cases of non filling in a series of 215 encephalographies from a paediatric department. No tumours were observed.

Of these authors, LINDGREN, as well as FALK and RUGGIERO, employed the method of LINDGREN (1949, 1950, 1954). SCHEINBERG & YAIR did not give

The cisterns were normal in 51 and could not be assessed in 17 of the 68 cases in which no tumour was demonstrated and in which the air did not enter the subdural space. Thirteen of these sixty eight cases were not subjected to repeat encephalography, ventriculography or arteriography, as the clinical examination and EEG had revealed no evidence to suggest the presence of an expanding intracranial lesion. Of these thirteen cases the cisterns were normal in eleven and could not be assessed in two cases.

Air entered the subdural space in 13 cases. Five of them were subjected to repeat encephalography. In one of these the air failed to enter the ventricular system, ventriculography was unsuccessful but biopsy from the cortex revealed sequelae of encephalitis. The films disclosed no abnormalities in three cases and atrophy in one. In two cases with epilepsy, ventriculography and carotid arteriography were found to be normal. Six of the thirteen cases were not subjected to any of these procedures and a diagnosis of a neoplasm could not be maintained.

No severe complications occurred in the ninety five cases examined. Convulsive seizures developed in four cases, including one with an acoustic neuroma. A fall in blood pressure occurred in ten cases, including one with a cerebellar abscess. Two patients became restless and confused, one of them had metastases in the cerebrum and cerebellum.

Discussion

ROBERTSON (1957) divided the cases of non filling of the ventricular system into obstructive and non obstructive. Obstruction of the foramen of Magendie may be caused by a tumour, a cyst, fibrous tissue or herniation of the cerebellar tonsils. He enumerated seven non obstructive causes, including three anomalies of the cisterna magna, viz the tall and the wide cisterna magna and failure of peripheral delimitation of the cisterna magna. Two other non-obstructive causes are flow anterior to the cervical spinal cord due to adhesions posteriorly or to too rapid injection of the air, and a narrow vallecula or foramen of Magendie. Finally, subdural and epidural injections were also classified as non-obstructive causes. ROBERTSON described how the difficulties involved can be overcome by changing the position of the neck and head and directing the air into the foramen of Magendie. We were unable to demonstrate that variations in the form and size of the cisterna magna could have been the cause of non filling of the ventricular system in any of the ninety five cases in our series, nor were any cases of herniation of the cerebellar tonsils encountered.

LINDGREN (1949, 1951), like ROBERTSON, particularly emphasized the importance of the position of the head for accomplishing filling of the ventricular system, this with reference to the tendency of gases to rise vertically in liquids

Table 2

Age distribution in the ninety-five patients with non filling of the ventricular system

Age years	Males	Females
<1	2	0
1-10	4	5
11-20	4	11
21-30	8	1
31-40	5	8
41-50	10	12
51-60	8	7
61-70	4	6
Total	45	50

in 19 cases (41.3%), including four (21.1%) in which expanding intracranial lesions were disclosed, in the remaining fifteen cases no tumour could be demonstrated. In the four cases with expanding intracranial lesions, the diagnosis was not made at the first examination. Repeat encephalography led to satisfactory filling in twenty-six cases and the films revealed no abnormality or atrophy. In one case only the fourth ventricle filled due to obstruction of the aqueduct, a finding confirmed by ventriculography. The patient in question had had meningitis and was subjected to operation at which a valve was inserted. This was the only confirmed case of stenosis of the aqueduct referable to adhesions or fibrosis, although it is possible that such a stenosis may also have been present in some of the other cases.

There were nine cases of meningitis or encephalitis. In three of these ventriculography had not been performed, and it had been unsuccessful in two cases. One case had undergone operation for an encephalocele in the occipital region and one case was considered to have carcinosis of the meninges arising from carcinoma of the cervix uteri, ventriculography was not performed in these two cases.

Five of six cases of infantile encephalopathy were subjected to repeat encephalography in which the filling was satisfactory although atrophy was present.

In five of the fourteen cases with an expanding intracranial lesion the diagnosis was made on the basis of the appearance of the cisterns, a tumour was suggested in one. The cisterns could not be assessed in seven cases and in one the basal cisterns were interpreted as normal, the latter was a case of a tumour in the midline, viz. an ependymoma of the fourth ventricle. The diagnosis was made by arteriography in four cases, in one by ventriculography and in four by arteriography plus ventriculography. The diagnoses were confirmed by operation in thirteen cases and by autopsy in one.

The cisterns were normal in 51 and could not be assessed in 17 of the 68 cases in which no tumour was demonstrated and in which the air did not enter the subdural space. Thirteen of these sixty-eight cases were not subjected to repeat encephalography, ventriculography or arteriography, as the clinical examination and EEG had revealed no evidence to suggest the presence of an expanding intracranial lesion. Of these thirteen cases the cisterns were normal in eleven and could not be assessed in two cases.

Air entered the subdural space in 13 cases. Five of them were subjected to repeat encephalography. In one of these the air failed to enter the ventricular system, ventriculography was unsuccessful but biopsy from the cortex revealed sequelae of encephalitis. The films disclosed no abnormalities in three cases and atrophy in one. In two cases with epilepsy, ventriculography and carotid arteriography were found to be normal. Six of the thirteen cases were not subjected to any of these procedures and a diagnosis of a neoplasm could not be maintained.

No severe complications occurred in the ninety five cases examined. Convulsive seizures developed in four cases, including one with an acoustic neuroma. A fall in blood pressure occurred in ten cases, including one with a cerebellar abscess. Two patients became restless and confused, one of them had metastases in the cerebrum and cerebellum.

Discussion

ROBERTSON (1957) divided the cases of non filling of the ventricular system into obstructive and non-obstructive. Obstruction of the foramen of Magendie may be caused by a tumour, a cyst, fibrous tissue or herniation of the cerebellar tonsils. He enumerated seven non-obstructive causes, including three anomalies of the cisterna magna, viz the tall and the wide cisterna magna and failure of peripheral delimitation of the cisterna magna. Two other non obstructive causes are flow anterior to the cervical spinal cord due to adhesions posteriorly or to too rapid injection of the air, and a narrow vallecula or foramen of Magendie. Finally, subdural and epidural injections were also classified as non obstructive causes. ROBERTSON described how the difficulties involved can be overcome by changing the position of the neck and head and directing the air into the foramen of Magendie. We were unable to demonstrate that variations in the form and size of the cisterna magna could have been the cause of non filling of the ventricular system in any of the ninety five cases in our series, nor were any cases of herniation of the cerebellar tonsils encountered.

LINDGREN (1949, 1954), like ROBERTSON, particularly emphasized the importance of the position of the head for accomplishing filling of the ventricular system, this with reference to the tendency of gases to rise vertically in liquids

Table 2

Age distribution in the ninety five patients with non filling of the ventricular system

Age years	Males	Females
<1	2	0
1-10	4	5
11-20	4	11
21-30	8	1
31-40	5	8
41-50	10	12
51-60	8	7
61-70	4	6
Total	45	50

in 19 cases (41.3 %), including four (21.1 %) in which expanding intracranial lesions were disclosed, in the remaining fifteen cases no tumour could be demonstrated. In the four cases with expanding intracranial lesions, the diagnosis was not made at the first examination. Repeat encephalography led to satisfactory filling in twenty six cases and the films revealed no abnormality or atrophy. In one case only the fourth ventricle filled due to obstruction of the aqueduct, a finding confirmed by ventriculography. The patient in question had had meningitis and was subjected to operation at which a valve was inserted. This was the only confirmed case of stenosis of the aqueduct referable to adhesions or fibrosis, although it is possible that such a stenosis may also have been present in some of the other cases.

There were nine cases of meningitis or encephalitis. In three of these ventriculography had not been performed, and it had been unsuccessful in two cases. One case had undergone operation for an encephalocele in the occipital region and one case was considered to have carcinosis of the meninges arising from carcinoma of the cervix uteri, ventriculography was not performed in these two cases.

Five of six cases of infantile encephalopathy were subjected to repeat encephalography in which the filling was satisfactory although atrophy was present.

In five of the fourteen cases with an expanding intracranial lesion the diagnosis was made on the basis of the appearance of the cisterns, a tumour was suggested in one. The cisterns could not be assessed in seven cases and in one the basal cisterns were interpreted as normal, the latter was a case of a tumour in the midline, viz. an ependymoma of the fourth ventricle. The diagnosis was made by arteriography in four cases, in one by ventriculography and in four by arteriography plus ventriculography. The diagnoses were confirmed by operation in thirteen cases and by autopsy in one.

The cisterns were normal in 51 and could not be assessed in 17 of the 68 cases in which no tumour was demonstrated and in which the air did not enter the subdural space. Thirteen of these sixty eight cases were not subjected to repeat encephalography, ventriculography or arteriography, as the clinical examination and EEG had revealed no evidence to suggest the presence of an expanding intracranial lesion. Of these thirteen cases the cisterns were normal in eleven and could not be assessed in two cases.

Air entered the subdural space in 13 cases. Five of them were subjected to repeat encephalography. In one of these the air failed to enter the ventricular system, ventriculography was unsuccessful but biopsy from the cortex revealed sequelae of encephalitis. The films disclosed no abnormalities in three cases and atrophy in one. In two cases with epilepsy, ventriculography and carotid arteriography were found to be normal. Six of the thirteen cases were not subjected to any of these procedures and a diagnosis of a neoplasm could not be maintained.

No severe complications occurred in the ninety five cases examined. Convulsive seizures developed in four cases, including one with an acoustic neuroma. A fall in blood pressure occurred in ten cases, including one with a cerebellar abscess. Two patients became restless and confused, one of them had metastases in the cerebrum and cerebellum.

Discussion

ROBERTSON (1957) divided the cases of non filling of the ventricular system into obstructive and non-obstructive. Obstruction of the foramen of Magendie may be caused by a tumour, a cyst, fibrous tissue or herniation of the cerebellar tonsils. He enumerated seven non-obstructive causes, including three anomalies of the cisterna magna, viz the tall and the wide cisterna magna and failure of peripheral delimitation of the cisterna magna. Two other non obstructive causes are flow anterior to the cervical spinal cord due to adhesions posteriorly or to too rapid injection of the air, and a narrow vallecula or foramen of Magendie. Finally, subdural and epidural injections were also classified as non-obstructive causes. ROBERTSON described how the difficulties involved can be overcome by changing the position of the neck and head and directing the air into the foramen of Magendie. We were unable to demonstrate that variations in the form and size of the cisterna magna could have been the cause of non filling of the ventricular system in any of the ninety five cases in our series, nor were any cases of herniation of the cerebellar tonsils encountered.

LINDGREN (1949, 1954), like ROBERTSON, particularly emphasized the importance of the position of the head for accomplishing filling of the ventricular system, this with reference to the tendency of gases to rise vertically in liquids

LINDGREN also pointed out that to prevent the collapse of cisterns and foramina it is most important that no cerebrospinal fluid is removed before the injection of gas.

We had relatively few cases in which the ventricular system failed to fill and among these were also relatively few that had an expanding intracranial lesion. FALK (1953) reported non filling in 5 % of his cases and a tumour was present in 26.7 % of these. His series consisted of 1841 encephalographies with a total of 195 cases of tumour. The corresponding figures reported by RUGGIERO (1957) were 7 % and 48.9 %, respectively. His series consisted of 670 encephalographies, of which also 195 were cases of tumour. Non filling in our series occurred in 1.4 %, of which 14.7 % had tumours. There were many cases with normal findings in our series. Discrepancies in relation to other series are probably due to differences in composition of the series.

The distribution between supratentorial and infratentorial tumours in our series is in good agreement with the series of FALK and of RUGGIERO, the infratentorial tumours being about twice as frequent as the supratentorial. FALK reported eight supra- and sixteen infratentorial tumours while RUGGIERO found six supra- and fourteen infratentorial tumours and three tumours with both supra- and infratentorial involvement.

There was only one case of confirmed stenosis of the aqueduct in our series while, as already mentioned, there were several cases with this lesion in the other series.

On repeat encephalography the ventricular system failed to fill in nineteen of our cases. Four of these had tumours, i.e. 21.1 %, as compared with 14.7 % at the first examination. However, as the number of repeat examinations was small, it is not obvious whether any definite difference was obtained. In the series described by SCHEINBERG & YAHIR (1955), non filling occurred in 24 cases at two or more examinations, tumours were present in about 70 % of these cases.

Encephalography performed under anaesthesia results in a higher frequency of non filling. In our series, 600 cases were examined under general anaesthesia, non filling occurred in 15 cases, i.e. in 2.5 %. A total of 6315 cases were investigated without anaesthesia, non filling occurred in 80 cases i.e. in 1.27 %. This difference, which is statistically significant, is in agreement with previously reported results. Thus, DAVIDOFF & DYKE (1951) recorded non filling in 12.7 % of their encephalographies performed under anaesthesia as against 7.3 % in their total series. It is possible, or perhaps even likely, that this difference could be due to compression of the jugular veins in the cases examined under anaesthesia since the head is suspended during the first films obtained in the sitting position.

In our fourteen cases of tumour, the diagnoses were established on assessment

of the cisternal conditions in nearly half the number of cases FALK (1953) diagnosed twenty-one out of twenty four tumours from the appearance of the cisterns

In our ninety five cases of non filling, a neoplasm was present in fourteen cases, stenosis of the aqueduct in one, and the air entered the subdural space in thirteen cases, in the remaining sixty seven cases no definite explanation of the absence of ventricular filling could be given, which represents about 1% of the whole series FALK in ninety cases of non filling observed a tumour in twenty four, arachnoiditis in four, stenosis of the aqueduct in three and found that obstructive lesions were possibly present in another sixteen cases This leaves forty three cases in which no explanation could be given, i.e. 23% of the total series RUGGIERO among his forty seven cases of non filling recorded a tumour in twenty three cases, stenosis of the aqueduct in four, and that the air passed subdurally in two cases He thus had eighteen cases in which no explanation of the non filling could be offered, i.e. 27% in a series of 670 cases The percentage in our series without an adequate explanation of non filling is thus relatively small

It must be emphasized that the present series is most comprehensive and comprises nearly 7 000 encephalographies When encephalography results in non filling, other things being equal, the chances of the presence of an expanding intracranial lesion are 14.7%

If the absence of ventricular filling is encountered in radiologic practice, the examiner must first make sure that this could not be due to herniation of the cerebellar tonsils The next step should be, as stressed by LINDGREN (1949, 1950), a detailed study of the cisterns and encephalography should be continued with films obtained with the patient supine and prone in order to achieve satisfactory demonstration of the supratentorial cisterns

SUMMARY

An analysis of 6915 cases subjected to encephalography within a 10-year period revealed that the ventricles failed to fill in 95 cases (1.4%) The causes of non filling of the ventricular system are discussed and the importance of a close examination of both the infra and supratentorial cisterns is emphasized

ZUSAMMENFASSUNG

Bei Durchsicht eines Materiales von 6915 Fällen, die während einer Periode von 10 Jahren enzephalographisch untersucht wurden, zeigte sich, dass in 95 Fällen (1.4%) keine Füllung der Ventrikel erzielt werden konnte Die möglichen Gründe hierfür werden besprochen und die Wichtigkeit einer gründlichen Untersuchung der infra und supratentoriellen Zisternen wird betont

LINDGREN also pointed out that to prevent the collapse of cisterns and foramina it is most important that no cerebrospinal fluid is removed before the injection of gas.

We had relatively few cases in which the ventricular system failed to fill and among these were also relatively few that had an expanding intracranial lesion. FALK (1953) reported non-filling in 5 % of his cases and a tumour was present in 26.7 % of these. His series consisted of 1841 encephalographies with a total of 195 cases of tumour. The corresponding figures reported by RUGGIERO (1957) were 7 % and 48.9 %, respectively. His series consisted of 670 encephalographies, of which also 195 were cases of tumour. Non-filling in our series occurred in 1.4 %, of which 14.7 % had tumours. There were many cases with normal findings in our series. Discrepancies in relation to other series are probably due to differences in composition of the series.

The distribution between supratentorial and infratentorial tumours in our series is in good agreement with the series of FALK and of RUGGIERO, the infratentorial tumours being about twice as frequent as the supratentorial. FALK reported eight supra- and sixteen infratentorial tumours while RUGGIERO found six supra- and fourteen infratentorial tumours and three tumours with both supra- and infratentorial involvement.

There was only one case of confirmed stenosis of the aqueduct in our series while, as already mentioned, there were several cases with this lesion in the other series.

On repeat encephalography the ventricular system failed to fill in nineteen of our cases. Four of these had tumours, i.e. 21.1 %, as compared with 14.7 % at the first examination. However, as the number of repeat examinations was small, it is not obvious whether any definite difference was obtained. In the series described by SCHEINBERG & YAHR (1955), non-filling occurred in 24 cases at two or more examinations, tumours were present in about 70 % of these cases.

Encephalography performed under anaesthesia results in a higher frequency of non-filling. In our series, 600 cases were examined under general anaesthesia, non-filling occurred in 15 cases, i.e. in 2.5 %. A total of 6315 cases were investigated without anaesthesia, non-filling occurred in 80 cases, i.e. in 1.27 %. This difference, which is statistically significant, is in agreement with previously reported results. Thus, DAVIDOFF & DYKE (1951) recorded non-filling in 12.7 % of their encephalographies performed under anaesthesia, as against 7.3 % in their total series. It is possible, or perhaps even likely, that this difference could be due to compression of the jugular veins in the cases examined under anaesthesia since the head is suspended during the first films obtained in the sitting position.

In our fourteen cases of tumour, the diagnoses were established on assessment

TOPOMETRIC POSITIONS OF VENOUS ANGLES IN INTRACRANIAL EXPANSIVE LESIONS

by

FRANZ P. PROBST

A method to determine the normal positions of the venous angles has previously been described (PROBST 1970). This method was also used in a number of cases with subdural hematomas (19 cases), intracerebral tumours (9 cases) and meningiomas (6 cases). The results obtained will now be considered.

The positions of the venous angles in 19 cases of subdural hematomas of varying degree and age (maximum thickness from 0.8 to 5 cm) are represented in Fig. 1. Cases 7, 12 and 19 had bilateral subdural hematomas which in Cases 7 and 19 were very large. All of the venous angles were situated below the X-axis, ten lying outside the 95 % prediction area but only four outside the 99 % prediction area. Cases 1, 3, 11 and 12 were re-examined after operation. The venous angles of Cases 3 and 11 had returned to what probably was their ordinary positions (3b and 11b). A residual hematoma in Case 1 had prevented the venous angle from regaining its normal site (1a). The hematomas of Case 12 were rather small (maximum thickness 1.7 and 1.0 cm) but postoperatively, at the time of re-examination, a large amount of air was present in the subdural space around the frontal parts of the brain. This probably explains the displace-

Submitted for publication 1 April 1969

RÉSUMÉ

L'analyse de 6915 encephalographies au cours d'une période de 10 ans a montré qu'il était impossible de remplir les ventricules dans 95 cas (1,4 %). L'auteur étudie les causes de non remplissage du système ventriculaire. Il insiste sur l'importance d'un examen attentif des citernes sous et sustentorielles.

REFERENCES

- DAVIDOFF L. M. and DYKE C. The normal encephalogram. Third edition, p. 68. Henry Kimpton, London 1951.
- FALK H. Encephalography in cases of intracranial tumor. *Acta radiol.* 40 (1953), 220.
- LINDGREN E. Some aspects on the technique of encephalography. *Acta radiol.* 31 (1949), 161.
- Lncephalographic examination of tumours in the posterior fossa. *Acta radiol.* 34 (1950), 331.
- Röntgenologie. In: *Handbuch der Neurochirurgie*. Band 2, p. 79. Springer Verlag Berlin, Göttingen, Heidelberg 1954.
- ROBERTSON E. G. Pneumoencephalography, p. 108. Blackwell, Oxford 1957.
- RUGGIERO G. L'encéphalographie fractionnée, p. 94. Masson et Cie, Paris 1957.
- SCHEINDERO L. and YAHIR M. The unsatisfactory pneumoencephalogram. *Trans. Amer. neurol. Ass.* 80 (1955), 221.
- SCHULLMAN I. Review of encephalogram done over a five year period. *Dis. nerv. Syst.* 14 (1953), 355.
- VISTEDAL J., FOGHT NIELSEN K. E. and THOMSEN G. Pneumoencephalography in a paediatric department. *Acta paediat.* 43 (1954), 120.

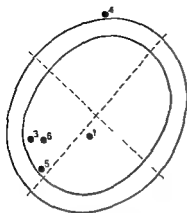
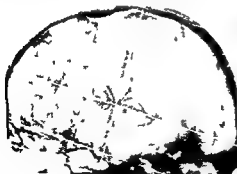


Fig 3 Positions of the venous angles in meningiomas situated in the parasagittal parietal region (Cases 1, 3, 6), parieto-temporally (Case 5) frontally (Case 2) and basally (Case 4)

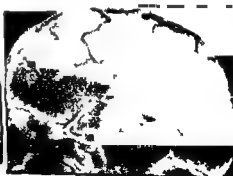
ment of the venous angle (12b) far posteriorly on to the posterior border of the 99 % prediction area. Case 19 is illustrated in Fig 2.

The positions of the venous angles in 6 cases of meningioma are given in Fig 3. Three of them were situated in the parasagittal parietal region (in Cases 1, 3 and 6), one in the parieto-temporal region (in Case 5) and two (in Cases 2 and 4) were situated frontally and basally, respectively. Only two angles were outside the 99 % prediction area. All of them, however, were located in the segment opposite to the tumour. The pre- and postoperative positions of the venous angle in Case 2 are demonstrated in Fig 4.

Of the nine cases with apparently well circumscribed tumours (gliomas and



a



b

the tumour
ial cerebral
b) After



Fig 1 Positions of the venous angles in 19 cases of subdural hematoma. Cases 7, 12 and 19 had bilateral hematomas. Cases 1, 3, 11 and 12 were re-examined after operation.

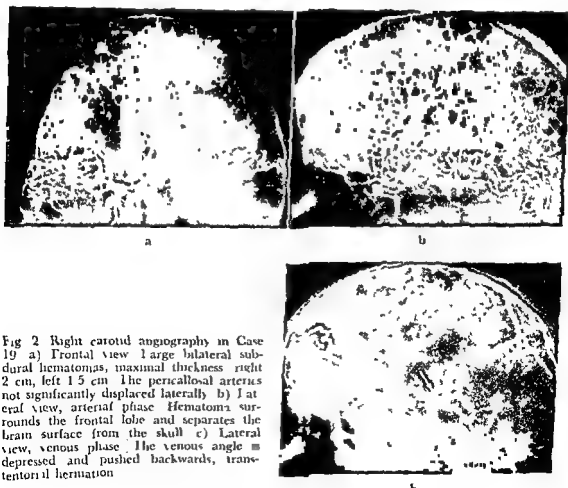


Fig 2 Right carotid angiography in Case 19. a) Frontal view. Large bilateral subdural hematomas, maximal thickness right 2 cm, left 1.5 cm. The pericallosal arteries not significantly displaced laterally. b) Lateral view, arterial phase. Hematoma surrounds the frontal lobe and separates the brain surface from the skull. c) Lateral view, venous phase. The venous angle is depressed and pushed backwards, trans-tentorial herniation.

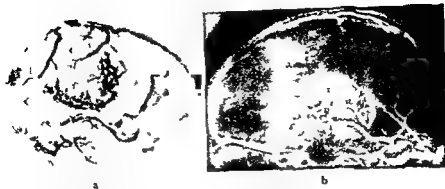


Fig 6 a) Globular metastatic tumour. Lateral ventricle deformed and venous angle depressed (Case 1 in fig 5) b) Basal glioma (Case 2 in fig 5). Venous angle far outside prediction areas

angle. This agrees well with the clinical experience that temporal tumours, in spite of being of considerable size, often do not displace the angiographic midline structures (especially the pericallosal artery) out of that plane.

In all cases of intracranial tumours (gliomas and meningiomas) the venous angles are situated in that segment of the topometrical figure that is opposite to the growth. Angles lying outside the prediction areas are considered to be displaced with that degree of probability achievable by the method. The others, situated within the prediction area for 95%, cannot individually be said to be displaced but, because of their position in the segment opposite the tumour, should have moved, at least in part.

Conclusion

Displacements not exceeding the borders of the 95% and 99% prediction areas are not recognizable because of the physiologic distribution of the venous angles within areas measuring as much as 110 and 169 mm², respectively. The assessment of displacements of the venous angles in the sagittal plane does not therefore achieve the same degree of accuracy as that of displacements across the midline. This metric method nevertheless seems to possess some advantages: it is not marred by subjectivity and permits any venous angle to be placed in relation to the calculated 0 point. The exact direction of deviations as well as of displacements thus becomes evident. This may be a diagnostic clue. The method gives also a definite indication of the tendency and, to some degree, the extent of the displacements in different groups of space-occupying intracranial lesions. The venous angles in uncomplicated subdural hematomas are depressed but return to

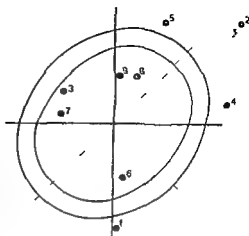


Fig 5 Positions of the venous angles in 11 cases of cerebral tumours (gliomas and one metastatic tumour). Attention may be drawn to the direction and the comparatively slight displacement of the venous angles in the four large temporal tumours (Cases 3, 7, 8 and 9)

one metastatic tumour), the venous angles of which are plotted in Fig 5, four angles were situated outside the 99 % prediction area, the others lay within the 95 % prediction area. All were located in the segment opposite to the tumour. Cases 1 and 2 are represented in Fig 6.

Discussion

Unilateral intracranial expansivities usually push the venous angle out of the median sagittal plane, antero-posterior compression and shortening of the internal cerebral vein may thus be imitated in the lateral view. Displacements of the midline structures in the median sagittal plane should be especially marked when symmetric pressure forces act on them as they cannot escape laterally. The movements (displacements) will then necessarily be confined to the median sagittal plane. The extent of the displacement is a result of the strength of the acting force, its direction is the main direction in a parallelogram of strengths. An example of this is the marked depression of the venous angles in symmetric bilateral subdural hematomas (Fig 1, Cases 7 and 19).

Subdural hematomas usually lie on the upper lateral surface of the brain. The central structures bearing the internal cerebral vein are thus depressed and except in the rare cases of symmetric bilateral hematomas, pushed across the midline. The extent of the depression naturally depends on the size of the hematoma being largest in large bilateral effusions. Should an effusion continue basally into the middle cerebral fossa or should there be an associated hematoma within the temporal lobe, it would be expected for the depression tendency to be counteracted. This is probably not the case because, as shown in Fig 5 (Cases 3, 7, 8, 9) even large temporal tumours often do not cause any significant elevation of the venous

FROM THE RADIUM CENTRE (DIRECTORS H. BJERRE HANSEN AND E. LAMBRETHSEN),
THE RADIATION PHYSICS DEPARTMENT (DIRECTOR P. OMSVEEN) AND THE ROENT-
GEN DIAGNOSTIC DEPARTMENT (DIRECTORS P. L. ANDERSEN AND E. LANGESEN),
ODENSE COUNTY AND CITY HOSPITAL, DENMARK

LYMPH NODE SCANNING WITH COLLOIDAL RADIOACTIVE GOLD

by

Sv. E. HARTING, P. BUCHLER-FREDERIKSEN, T. JAGT and P. JEPPESEN

Major surgery was formerly necessary to reveal pathologic changes in lymph nodes not easily palpated, e.g. those located in the lesser pelvis and the retroperitoneal space. It is, of course, possible to reveal enlargement of lymph nodes by means of various roentgenologic examinations. Organs may present deformities or displacements corresponding to the enlarged lymph nodes, or changes in the shape of the mediastinum may be revealed at ordinary chest roentgenography.

The introduction of contrast lymphography made it possible to obtain fair detail of the normal or pathologic lymphatic system (WILJASALO 1965, EIKEN 1965). This method has proved of almost revolutionary importance as a diagnostic aid in the detection of malignant disease and not least where examinations of malignant lymphomas are concerned. The technique is however somewhat complex and requires skill and special training. It can be rather unpleasant for the patient, inter alia because it is a fairly lengthy procedure. It must also be borne in mind that the examination, although rarely, may have serious side effects even if it is performed in a perfect manner. Under such circumstances, a less strenuous method of examination, which could provide information on the condition of the lymph nodes, should be welcome, particularly if reasonably accu-

normal positions soon after a successful operation. Intracranial tumours move the venous angles in the direction to be expected from the position of the masses. The degree of displacement depends on the size of the lesion. Temporal growths seem to change the position of the venous angle to a lesser degree and later in development than those situated frontally and parietally.

SUMMARY

The positions of the venous angles in the median sagittal plane in different expanding intracranial lesions have been determined by the method described in a previous paper. Some preliminary conclusions are drawn.

ZUSAMMENFASSUNG

Die Lage der Venenwinkel in der Mediansagittalebene wurde in verschiedenen Fällen von intracerebralen expansiven Prozessen mittels der in einem früheren Artikel beschriebenen Methode bestimmt. Einige preliminary Folgerungen wurden gezogen.

RÉSUMÉ

La position de l'angle veineux dans le plan sagittal médian a été déterminée au moyen de la méthode décrite dans un article précédent dans différents types de lésion expansive intracrânienne. L'auteur tire des conclusions préliminaires.

REFERENCE

- PROBST F. P. Position of the 'venous angle' in the median sagittal plane. A new topometric method. *Acta radiol. Diagnosis* 10 (1970) 271.

Table 2

Findings in 39 patients in whom contrast lymphography and lymph node scanning gave similar results

	Correlation of findings on both sides			Contrast lymphography on one side only		Total
	Both sides pathologic	Both sides non pathologic	One pathologic, one normal side	Pathologic	Normal	
Hodgkin's disease	7	3	1	2	2	15
Other malignant diseases of the reticuloendothelial system	6	2	1	3	—	12
Carcinoma	1	8	2	1	—	12
Total	14	13	4	6	2	39

must not exceed 0.5 ml on each side. The scanning is carried out 24 hours after the injection, with a Picker Magnascanner having a crystal diameter of 5" and a depth focusing collimator. The adjustment of the apparatus is made according to the depth and amount of activity of the para-aortic lymph nodes.

It is most important that the patient is ambulatory immediately after the injection of the colloid, to ensure a sufficiently effective distribution of the lymph. If the examination is to be repeated later, another interdigital space must be selected, to avoid doubling the radiation dose at the site of injection.

Normal and pathologic scintigrams. The normal scintigram will show a continuous symmetric chain of lymph nodes from the groin to the diaphragm, the liver will also generally be faintly visible.

Pathologic changes in the lymph nodes will usually in the scintigram appear as breaks in the lymph chain due to the inability of diseased lymph nodes to accumulate colloid particles. The distance between the individual lymph nodes often varies somewhat but this will only on rare occasions give rise to misinterpretations, since the pathologic breaks in the chain are considerably wider than the normal variations. Such information about structural changes as is obtainable with isotope lymphography, cannot be obtained with contrast lymphography, because pathologic changes in the lymph nodes will produce a total break in the lymph node chain. Large defects in markedly enlarged lymph nodes may however occasionally be visible, depending on the resolution properties of the apparatus employed. Furthermore, activities outside the normally located chains may be

Table 1

Classification of the patients into disease groups

	With contrast lymphography	Without contrast lymphography	Total
Hodgkin's disease	17	2	19
Diseases of the reticuloendothelial system	14	14	28
Carcinomas	16	14	30
Total	47	30	77

rate differentiation between pathologic and normal lymph nodes, even without much detail, could be achieved. An examination of this nature would be valuable as a screening test as well as for repeat controls in chronic disorders.

The lymph nodes of the pelvis and the retroperitoneal space may be demonstrated by means of the lymph node scanning technique. This method is not complex and causes only slight discomfort to the patient. Radioactive colloidal gold is injected subcutaneously in the feet, and within 24 hours the lymph will carry the colloid to the abdominal lymph nodes. Scanning will then reveal in detail the lymph node chains running from the groin to the diaphragm. Several authors (DELAHOYE & MAGENAT 1961, JUCKER 1966, KAZEM *et coll* 1968, SCHENK 1966, VOUTILAINEN & WILJASALO 1965 and ZUM WINKEL & MULLER 1965) have claimed that the method is sufficiently accurate to be used as a screening test and a control for assessing the effects of treatment. It has sometimes been possible to obtain information to supplement the findings at contrast lymphography. The method is claimed to be completely safe.

The object of the present investigation was to test the method and to find out if it will meet the requirements mentioned.

Method. Colloidal radioactive gold, ^{198}Au , with a particle diameter of 8 to 10 millimicrons is employed. It is important that the particle size is just within this order of magnitude, because if particles of a greater diameter are used, e.g. the usual size of 30 millimicrons, the accumulation in the inguinal lymph nodes will be too great, and the pool of colloid in the abdominal lymph nodes will be inadequate. Should the diameter be considerably smaller than 8 to 10 millimicrons, the amount of colloid throughout the chain of lymph nodes would be inadequate.

About 100 to 120 microcurie ^{198}Au , together with 75 units of hyaluronidase and a 0.5% solution of novocaine without noradrenalin, are injected subcutaneously in the first interdigital space dorsally in the feet. The volume injected



Fig 2 Lymph node scan (a) and contrast lymphography (b) in a patient with malignant lymphogranulomatosis in whom pathologic conditions corresponding to the left lymph node chain were demonstrated. No filling of the para-aortic lymph nodes. Pathologic lymph nodes with metastases were present on the left side (b).

Material The series comprised 77 cases in which lymph node scanning was carried out over the period from February 1967 to February 1968. In 47 of these contrast lymphograms were also available which could be compared with the isotope lymphograms. In the remaining 30 cases attempts were made to elucidate the results of the examination by means of an assessment of the clinical course, results of exploratory laparotomies and autopsy findings.

The distribution of the material into the disease groups malignant lymphogranulomatosis, other malignant diseases in the reticulo-endothelial system and carcinomas is given in Table 1. The findings at lymph node scanning and at contrast lymphography were compared in the forty-seven cases in which both examinations were performed. The diagnoses that had primarily been made at the Department of Diagnostic Radiology were employed as a standard for the comparison without retrospective revision of the material or of the scannings.

Table 2 represents the results relating to the 39 cases in which the two examinations were similar. Contrast lymphography in eight cases was successful on one side only but the results on the other side agreed well with the findings at scanning.

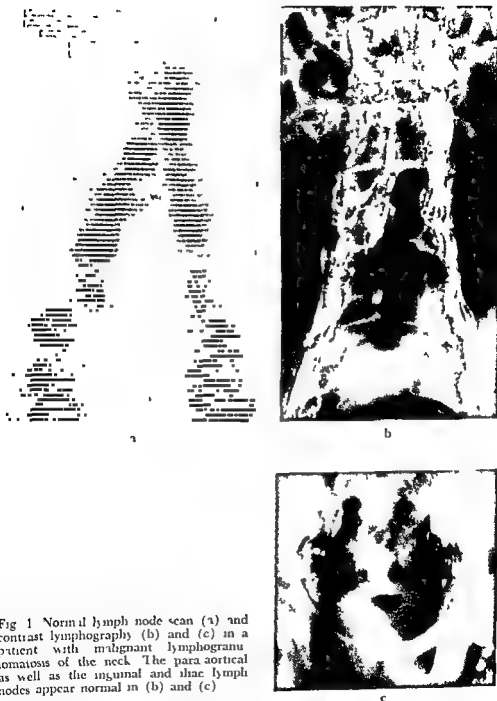


Fig 1 Normal lymph node scan (a) and contrast lymphography (b) and (c) in a patient with malignant lymphogranulomatosis of the neck. The para aortical as well as the inguinal and iliac lymph nodes appear normal in (b) and (c).

demonstrated. These changes may be caused partly by formation of collaterals and partly because of displacement of the lymph nodes as a consequence of space-occupying processes in adjacent organs.



Fig 3 a) Lymph node scan. Marked changes with recesses both in the right and the left lymph node chain and enlarged lymph nodes outside the normal location of lymph nodes. b) Contrast lymphography. Marked changes on both sides.

Thus, normal scintigrams were obtained in eleven of the thirty cases, as expected, since there had been no clinical signs of lesions of the abdominal lymph nodes in these cases. Pathologic lymphographic scintigrams were obtained in nineteen cases, in the seven cases in which surgery or autopsy was performed, the scintigrams showed pathologic abdominal lymph nodes.

The results of the lymphographic scannings were in some of the remaining cases most likely correct when assessed on the basis of clinical considerations. This assessment is however of no great value and will not be elaborated upon.

Discussion

The results obtained confirm previous observations made by other workers that contrast lymphography and lymph node scanning are usually in good agreement. The present material is limited, and conclusions should therefore be drawn with some reservations. Employed as a screening test, lymph node scanning may be considered sufficiently safe and accurate. It may in individual

Röntgenologic examination and scanning failed to concur in eight cases. Surgery revealed agreement with the findings at scanning in four cases, in two cases the scanning results were not the same as the surgical findings and two cases in which contrast lymphography and scanning did not agree were not verified surgically. It must therefore be presumed that the scanning had failed in four cases.

False normal lymph node chains were observed in two cases and false pathologic lymph node chains in two cases. False normal scintigrams (false negatives) represent the most serious drawback of the method when it is applied for screening purposes since such scintigrams may result in a discontinuance of the examination. The two false pathologic findings did not essentially invalidate the examination from a screening point of view. False positive scintigrams will only cause further examinations to be carried out, i.e. contrast lymphography.

The misinterpretations of our scintigrams were due partly to the fact that the scanning was carried out in one plane only — hence no displacement of the lymph node chains perpendicular to the scanning plane could be demonstrated — and partly to an unusually wide normal variation in the distance between the individual lymph nodes.

The evaluations of the lymph node scintigrams in the thirty cases in which contrast lymphography had not been performed are presented below comprising nineteen pathologic and eleven non pathologic scintigrams.

Pathologic scintigrams were obtained in 19 cases according to the following

Cavography showed deformity corresponding to lymph nodes	1
----------------------------------------------------------	---

Clinically localized reticulum cell sarcoma corresponding to one inguinal region and normal scintigram on the other side	2
--------------------------------------------------------------------------------------------------------------------------	---

Generalized reticulum cell sarcoma with universal gland swelling	5
------------------------------------------------------------------	---

Operation disclosed pathologic glands on both sides	2
-----------------------------------------------------	---

Autopsy showed pathologic glands on both sides	5
------------------------------------------------	---

No check up, apart from the clinical examination	4
--------------------------------------------------	---

Non pathologic scintigrams were registered for 11 cases as follows

Malignant disease not demonstrated	1
------------------------------------	---

Cerebral tumour, other diseases not known	1
-------------------------------------------	---

Lung cancer liver metastases	1
------------------------------	---

Clinically localized disease of the neck (Brill-Symmer's disease and transitional carcinoma)	3
----------------------------------------------------------------------------------------------	---

Minor abdominal surgery (appendectomy) no pathologic glands were observed	1
---------------------------------------------------------------------------	---

No clinical signs of pathologic lymph nodes and no decisive follow up result	4
------------------------------------------------------------------------------	---

ditions to any degree of accuracy. Other authors have suggested that about two-thirds of the isotope disappear within the first 24 hours.

We measured the volume of the isotope and examined its distribution by scanning in seven cases. It was found that the volume of isotope retained varied from 29 to 98 % of the volume injected. By scanning over the dorsum of the foot, the isotope proved to be located in the subcutis in areas ranging from 1.5 to 14 cm² in size. From these values the most frequent radiation dose was estimated to be 700 to 2 000 rad, and sometimes about 3 000 rad, when the entire volume of isotope remained at the site of injection. These radiation doses will usually cause no damage.

Radiation necroses were not observed in the present material but this complication may be within the range of possibilities. It cannot be precluded, from a theoretical point of view, that radiation induced malignant tumours might occur many years later, although presumably this will happen only infrequently. As the method is intended for use as a safe screening test, it must be admitted that in this respect it does not fully comply with the requirements.

As regards irradiation of the remaining parts of the body, it has been reported in the literature that the dose to the liver and the gonads ranges between 0.5 and 1 rad from one examination.

The method relies upon the fact that lymph nodes accumulate colloids of a certain dimension, and it should be possible to use the technique also with other colloids. This has been attempted (SCHENK 1966) but the most favourable result from a diagnostic point of view has been obtained with the gold colloid. Nevertheless, the high radiation dose to the foot makes it necessary to seek other isotopes of colloid compounds, preferably short lived isotopes emitting only gamma rays, by means of which the diagnostic outcome can at the same time be improved.

However, as the method is intended for use in cases of malignant disease, in which a deficient diagnosis may present a considerably higher risk than the risk run by the exposure of the patient to the lymph node scanning now described, it may yet be recommended in spite of the relatively high radiation dose to the interdigital space of the foot.

SUMMARY

Isotope lymphography was carried out over a period of one year in 77 patients suffering from malignant disease. Contrast lymphography was performed in connection with the scanning in 47 of the patients, and the results were used as a standard for comparison. In the remaining 30 patients the surgical and clinical findings were used as a basis for the evaluation. The good agreement obtained suggests that lymph node scanning is sufficiently safe and accurate as a screening test and for control examinations.

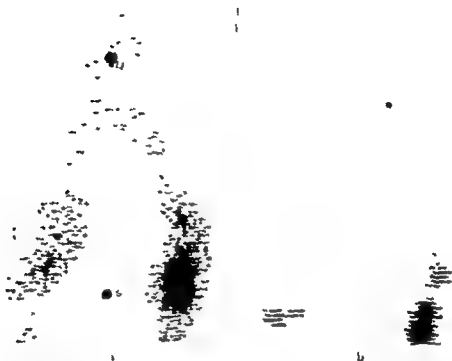


Fig. 1. Lymph node scans in a patient with malignant lymphogranulomatosis. Attempts at contrast lymphography failed, presumably because this had been carried out 15 years previously. a) The patient had no symptoms at the time of scanning, slight changes on both sides. b) Nine months later the patient had raised temperature, itching of the skin and an increased tendency to perspiration.

cases provide information supplementing the results obtained with contrast lymphography, and it is well suited for follow-up examinations on an out-patient basis.

The isotope lymphogram does not reveal the structures of the individual lymph nodes, which is an important feature of the diagnostic merits of contrast lymphography. For both examination methods applies that the pathologic findings are not specific of malignant disorders, and this may give rise to some difficulties as far as the differential diagnosis is concerned.

As regards side effects, a prolonged bluish discoloration of the skin on the dorsum of the foot, around the site of the injection, was observed in some cases. Oedema occurred in a few cases at the sites of injection and lasted for a few days but it then disappeared rapidly and caused no pain or other discomfort.

It was difficult to assess the radiation dose to the site of injection, because the radioactive substance disappears from the feet at a somewhat varying rate. To this should be added that it is difficult to determine the radiation geometric con-

VENOUS COMMUNICATIONS OF THE ADRENAL GLANDS

Anatomic and circulatory studies

by

C G MIKAELSSON

The anatomy of the efferent vein from the left adrenal gland, in the series of epinephro-phlebographies described earlier (MIKAELSSON 1969), was the same in all the twenty-three glands examined by the author's modified technique. In every instance there was one draining vein of normal anatomic appearance from each adrenal gland and no other drainage from the intraglandular veins could be observed. Attempts at catheterization of the right adrenal vein in 51 instances were successful in only 36, and as catheterization was not facilitated towards the end of the series, despite increasing experience, it seemed likely that some obstruction of anatomic nature to the catheterizations might be present. The films from the phlebographic series were also found to be suitable for a study of the direction of flow after injection of contrast medium into the veins of the adrenal glands and into extraglandular vessels.

This work was financially supported by Grant B69 61P 2601-01 from the Swedish Medical Research Council. Submitted for publication 24 June 1969

ZUSAMMENFASSUNG

Isotopenlymphographie wurde während eines Jahres in 77 Patienten mit malignen Krankheiten angewandt. In 47 von diesen Patienten wurde Kontrastmittellymphographie gleichzeitig ausgeführt und die Resultate wurden als Vergleichsstandard benutzt. In den übrigen 30 Patienten dienten die chirurgischen und klinischen Befunde als Grund für die Beurteilung. Die gute Übereinstimmung der Resultate deutet darauf hin, dass Isotopenlymphographie eine genügend sichere und zuverlässige Methode ist, um bei Screening und Kontrolluntersuchungen verwendet zu werden.

RÉSUMÉ

Pendant une période d'un an les auteurs ont fait des lymphographies isotopiques chez 77 malades atteints d'affection maligne. Les résultats de la lymphographie isotopique ont été comparés à ceux de la lymphographie par moyen de contraste chez 47 de ces malades et comparés aux constatations chirurgicales et cliniques chez les 30 autres malades. La bonne concordance obtenue fait penser que la scintigraphie des ganglions lymphatiques est une méthode sans danger et suffisamment précise comme test de dépistage et comme examen de contrôle.

REFERENCES

- DELAHOYE B et MAGNENAT P. La lymphographie indirecte et son intérêt en oncologie. Med ical Radioisotope Scanning Symposium p 227 Athens 1964
- EIKEN M. Lymfografi (In Danish). Nord Med 73 (1965) 264
- JUCKER V A. Lymphknotenszintigraphie mit kolloidalem Radiogold. Radiol clin Bol 35 (1966) 463
- KAZEM L, ANTONIADES J, BRADY L et coll. Clinical evaluation of lymph node scanning utilizing colloidal gold 198. Radiology 90 (1968) 905
- SCHENK P. Szintigraphische Darstellung des parasternalen Lymphsystems. Strahlentherapie 130 (1966) 504
- VOUTILAINEN A and WILJASALO M. On the correlation of lymphography and lymphoscintigraphy in metastases of tumours of the pelvic region. Ann Chir Gynaec Fenn 54 1965: 268
- WILJASALO M. Lymphographic differential diagnosis of neoplastic diseases. Acta radiol (1965) Suppl No 247
- ZUM WINKEL K und MÜLLER H. Technik, Auswertung und röntgenologische Kontrolle der abdominalen Isotopenlymphographie. Radiologe 5 (1965) 381

VENOUS COMMUNICATIONS OF THE ADRENAL GLANDS

Anatomic and circulatory studies

by

C G MIKAELSSON

The anatomy of the efferent vein from the left adrenal gland, in the series of epinephro-phlebographies described earlier (MIKAELSSON 1969), was the same in all the twenty three glands examined by the author's modified technique. In every instance there was one draining vein of normal anatomic appearance from each adrenal gland and no other drainage from the intraglandular veins could be observed. Attempts at catheterization of the right adrenal vein in 51 instances were successful in only 36, and as catheterization was not facilitated towards the end of the series, despite increasing experience, it seemed likely that some obstruction of anatomic nature to the catheterizations might be present. The films from the phlebographic series were also found to be suitable for a study of the direction of flow after injection of contrast medium into the veins of the adrenal glands and into extraglandular vessels.

This work was financially supported by Grant B69 61P 2601-01 from the Swedish Medical Research Council. Submitted for publication 24 June 1969

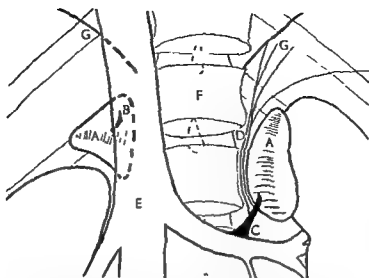


Fig 1 Position of adrenal glands in relation to kidneys and spinal column and the venous drainage to the vena cava and left renal vein A = adrenal glands with dorsal crest B = right adrenal vein C = left adrenal vein D = left inferior phrenic vein E = vena cava with renal veins F = twelfth thoracic vertebra G = diaphragm

Earlier investigations

The appearances of the adrenal glands and their vasculature according to earlier authors will be discussed first

The left gland is more elongated than the right, and its thickest portion — the head according to DOBBIE & SYMINGTON (1966) — is directed inferiorly while the body and tail point in a cranio-lateral direction. The hilum with the large efferent vein lie on the ventral surface of the head. Along the dorsal surface, a ridge-like elevation between the caput and cauda, the crest, slopes laterally, and a deep groove is formed between the ridge and the lateral portion of the gland. A shallower groove on the ventral surface corresponds to the crest on the other side (DOBBIE & SYMINGTON 1966, MERKLIN & EGER 1961) (Figs 1 and 2)

The right gland is more or less triangular. Its head is located in the medial portion, the ventral surface of which together with the hilum and efferent vein lie immediately adjacent to the right dorsal part of the vena cava wall. A crest runs on the dorsal surface between the head and tail, and the latter part of the gland is directed towards the right (ANSON et coll 1947, GAGNON 1956, DOBBIE & SYMINGTON 1966)

Each gland consists in reality of two distinct organs — the cortex, a derivative of the coelomic epithelium near the cranial pole of the mesonephros, and the

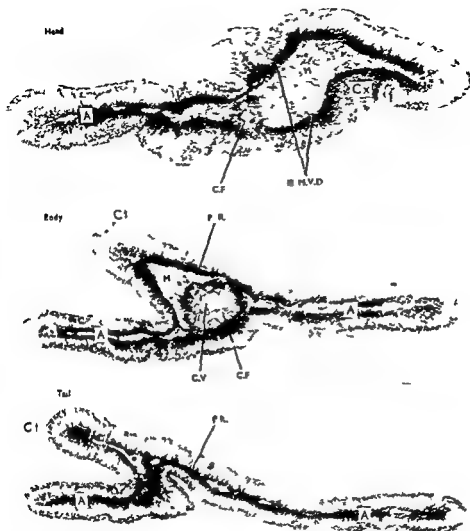


Fig. 2. Sections through the head (upper view), body (middle view) and tail (lower view) of the left adrenal gland $\times 6$. The dorsal surface with the crest faces upwards. A = alae with alar raphe. Cx = cortex. CF = cortical cuff. PR = plexus reticularis. CMVD = cortico-medullary vascular dam. Ct = crest. CV = central vein. M = medulla. (Slightly modified from DOBBIE & SYMINGTON 1966.)

medulla which develops from the sympathetic trunk. The two organs unite during embryonic development, the cortex moving downwards and the medulla upwards to penetrate into the cortex (BROMAS 1927, MERKLIN & MICHELIS 1958). The medulla is located mainly in the central area of the head segment.

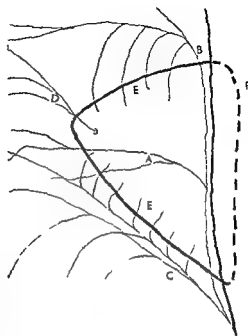


Fig 3 Right adrenal gland with superficial veins (A) communicating with right inferior phrenic vein (B) C = renal capsule veins D = emissary vein E = concomitant veins F = vena cava

and takes up approximately one-quarter of its mass while the tail is composed wholly of cortex, as are also the wings of the glands, the so-called alae (DOBBIE & SYMINGTON 1966) (Fig 2)

Arteries The highly diversified blood supply of the adrenal glands is considered to be explained by the embryonic development. These arteries are usually divided into three main groups according to the following vessels of origin: (1) the inferior phrenic arteries and celiac artery, (2) the aorta, and (3) the renal and gonad arteries. Branches from these stems divide in the fatty capsule of the adrenal glands into a large number of fine vessels that enter the gland and mainly supply its subcapsular capillary network. A few arteries penetrate more deeply into the cortex and medulla (GERARD 1913, ANSON et coll 1947, BUSCH 1955, GAGNON 1957, MERKLIN & MICHELS 1958, MERKLIN 1962, DOBBIE & SYMINGTON 1966, LINDVALL & SLEZAK 1969, and others)

Peripheral veins A large number of small concomitant veins more or less follow the arteries and like them may be divided into three groups (GAGNON 1956, BOBROVA 1965, SHDANOW & SSAPIN 1968, and others): (1) the cranial group running to the inferior phrenic vein, which usually empties into the vena cava, (2) the middle group, which connects up with (3) the inferior group. The latter vessels are closely associated with their corresponding arteries, but there are more

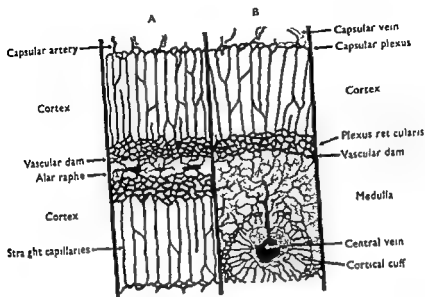


Fig 4 Transverse section showing the vascular system of an adrenal gland A part of the gland with medulla lacking B medulla present (From DOBBIE & SYMINGTON 1966)

veins than arteries. These veins run to vessels in the renal capsule, or directly to the vena cava.

Other veins of varying size run on the surface of the adrenal glands, and either anastomose with veins in the diaphragm or renal capsule (BOBROVA 1965), or are in direct communication with the intraglandular, central adrenal veins, they are then known as emissary veins (KUTSCHERA AICHBERGEN 1922, MERKLIN & EGER 1961, DOBBIE & SYMINGTON 1966, and others) (Fig 3). Communications with the portal system, via the pancreas on the left side and the hepatic capsule on the right, have been reported (KUTSCHERA AICHBERGEN 1922, BUSCH 1954/55, and others), as well as anastomotic connections with the vena azygos and vena hemiazygos (GAGNON 1956).

Capillaries The subcapsular capillary network on the surface of the adrenal glands continues into the cortex, some of the capillaries penetrating directly downwards through the two upper cortical zones to form a new, richly diversified network in the reticular zone (MERKLIN 1962, and others) (Fig 4). This network is sharply demarcated on the inner side of the cortex, in an arrangement called the vascular dam (VELICAN 1947).



Fig 5 Openings of right and left adrenal veins into the vena cava and left renal vein. Intra glandular veins (\rightarrow), superficial veins (\leftrightarrow), and emissary vein ($\leftrightarrow\leftrightarrow$) anastomosing with renal capsule and phrenic veins



Fig 6 A large liver vein between the right adrenal and renal veins. The left adrenal vein opens into the dorsal cranial shank of a peri aortal ring. Central adrenal veins (\rightarrow), inferior phrenic veins (\leftrightarrow), emissary vein ($\leftrightarrow\leftrightarrow$), cut off hepatic vein ($\leftrightarrow\leftrightarrow\leftrightarrow$)

Central veins From the inner network of capillaries in the cortex, small veins converge in the alae within the so-called alar raphe and unite into larger and larger vessels (Fig. 4). Many of the larger veins pass through the medulla and are usually surrounded by an invaginated cuff of cortical tissue, their adventitia consisting of longitudinal muscle fibres. Other veins in the alar raphe and medulla have no cortical cuff and consist only of a single layer of endothelium. These open into the muscular vessels, either between the bundles of muscle fibres or through slits in the bundles (MARESCH 1921, DOBBIE & SIMINGTON 1966, and others). Near the hilum, the muscular elements of the central veins envelop the circumference and further towards the periphery thin out into scattered muscle bundles that often protrude into the lumina of the veins. They are mainly located on the medulla facing segment of the veins (DOBBIE & SIMINGTON 1966). Some muscle fibres extend from the venous walls out into the parenchyma of the gland (MARESCH 1921, and others). Arcade like anastomoses which, according to SHIDANOW & SSAPIN (1968) increase in numbers in connection with hypertension, are found between the peripheral ramifications of the central venous system.

Efferent veins On the left side, the veins unite into one vein stem or a few vessels that rise in the crest in the tail portion of the gland and run obliquely through it (DOBBIE & SIMINGTON 1966). They pass through the hilum as one vein. After having received the inferior phrenic vein from the medial side, the vein runs inferiorly and slightly medially for a distance of 2 to 4 cm towards the renal vein, usually entering it about 2 to 5 cm from the vena cava (GAGNON 1956, and others). In the right adrenal gland, several stems usually converge to unite in the hilum into an efferent vein that is very short (1 to 5 mm). This vein runs medially, often also cranially, to the right dorsal portion of the vena cava wall (ANSOY et coll. 1947, GAGNON 1956, and others).

Opinions differ however regarding possible anatomic variations in the draining veins. ANSOY et coll. (1947), in 425 autopsies, examined the entire retroperitoneal venous system including the adrenal veins. GAGNON (1956) carried out 116 necropsies, paying special attention to the adrenal veins and examining 100 on each side. The veins had not been prepared, and he made the reservation that small veins could have been missed. HEINILAARA (1953/54) studied the adrenal veins in 29 autopsies, CLARK (1958/59) reported on 16 necropsies and JOHNSTONE (1957) made a similar study in 10 instances after intravenous injection of latex. He also measured the width of the veins but did not mention how this was done.

As regards the left side, CLARK noted in five instances that in addition to the ordinary vein from the hilum a wide vein ran between the dorsal surface of the adrenal gland and the renal vein. All the other authors reported that there was



Fig 5 Openings of right and left adrenal veins into the vena cava and left renal vein. Intra-glandular veins (\rightarrow), superficial veins (\mapsto), and emissary vein ($\mapsto\mapsto$) anastomosing with renal capsule and phrenic veins



Fig 6 A large liver vein between the right adrenal and renal veins. The left adrenal vein opens into the dorsal cranial shank of a peri aortal ring. Central adrenal veins (\rightarrow), inferior phrenic veins (\mapsto), emissary vein ($\mapsto\mapsto$), cut off hepatic vein ($\mapsto\mapsto\mapsto$)

Central veins From the inner network of capillaries in the cortex, small veins converge in the alae within the so-called alar raphe and unite into larger and larger vessels (Fig. 4). Many of the larger veins pass through the medulla and are usually surrounded by an invaginated cuff of cortical tissue, their adventitia consisting of longitudinal muscle fibres. Other veins in the alar raphe and medulla have no cortical cuff and consist only of a single layer of endothelium. These open into the muscular vessels, either between the bundles of muscle fibres or through slits in the bundles (MARESCH 1921, DOBBIE & SYMINGTON 1966, and others). Near the hilum, the muscular elements of the central veins envelop the circumference and further towards the periphery thin out into scattered muscle bundles that often protrude into the lumina of the veins. They are mainly located on the medulla facing segment of the veins (DOBBIE & SYMINGTON 1966). Some muscle fibres extend from the venous walls out into the parenchyma of the gland (MARESCH 1921, and others). Arcade like anastomoses which, according to SHIDANOV & SSAPIN (1968) increase in numbers in connection with hypertension, are found between the peripheral ramifications of the central venous system.

Efferent veins On the left side, the veins unite into one vein stem or a few vessels that rise in the crest in the tail portion of the gland and run obliquely through it (DOBBIE & SYMINGTON 1966). They pass through the hilum as one vein. After having received the inferior phrenic vein from the medial side, the vein runs inferiorly and slightly medially for a distance of 2 to 4 cm towards the renal vein, usually entering it about 2 to 5 cm from the vena cava (GAGNON 1956, and others). In the right adrenal gland, several stems usually converge to unite in the hilum into an efferent vein that is very short (1 to 5 mm). This vein runs medially, often also cranially, to the right dorsal portion of the vena cava wall (ANSON *et coll.* 1947, GAGNON 1956, and others).

Opinions differ however regarding possible anatomic variations in the draining veins. ANSON *et coll.* (1947), in 425 autopsies, examined the entire retroperitoneal venous system including the adrenal veins. GAGNON (1956) carried out 116 necropsies, paying special attention to the adrenal veins and examining 100 on each side. The veins had not been prepared, and he made the reservation that small veins could have been missed. HEINILAARA (1953/54) studied the adrenal veins in 29 autopsies, CLARK (1958/59) reported on 16 necropsies and JOHNSTONE (1957) made a similar study in 10 instances after intravenous injection of latex. He also measured the width of the veins but did not mention how this was done.

As regards the left side, CLARK noted in five instances that in addition to the ordinary vein from the hilum a wide vein ran between the dorsal surface of the adrenal gland and the renal vein. All the other authors reported that there was

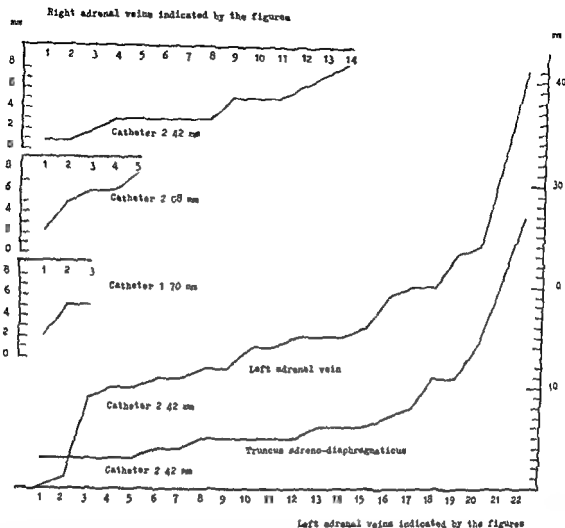


Fig 7 Diagram showing how the adrenal veins were catheterized. Each case that was catheterized is marked on the abscissas and the catheterizable lengths of the veins on the ordinates measured in mm. The whole length of the truncus adreno-diaphragmaticus could always be catheterized and is shown independently of the catheter length of the left adrenal vein proper.

only one adrenal vein and that this ran to the renal vein. JOHNSTONE however observed in one instance an accessory vein running to the veins in the renal capsule.

As regards the right side, the first three investigators stated that a single vein always ran between the adrenal gland and the vena cava. CLARK's and JOHNSTONE's observations differed. CLARK observed in seven instances another large vein running from the head of the gland to the vena cava, and JOHNSTONE found that in five instances the efferent vein opened into a liver vein and in one instance into a rudimentary vena cava on the right side located between the renal vein and



Fig 1 Two extraglandular veins running to the right adrenal vein and a vein in the ventral sulcus of the left adrenal gland (arrows) running to the efferent vein in the hilum. No other connections between intra- and extraglandular vessels are visible

the atrium. The vena cava was of normal size on the left side. In two instances the adrenal vein was divided into two or three vessels respectively, opening into the vena cava. Only two veins emptied single into the vena cava, and one of them was only 2 mm wide. In the case, in which three adrenal veins were present, the largest was 2.5 mm wide. In the other cases there was always a vein measuring at least 3 mm in width that ran from each adrenal gland.

Present investigation

Material. A series of 22 necropsy specimens were studied. These were taken from 11 female and 11 male bodies, from patients over 50 years of age who had died of cerebral or cardiac diseases. The anatomic studies were mainly carried out to investigate the direct venous communications between the large central veins of the adrenal glands and the vena cava together with its tributaries.

Films from the phlebographies previously carried out by the writer in 25 adrenal glands on the right side and 36 on the left side were also studied. These examinations were performed with a film changer, in patients with essential or renal hypertension, and there were no complications or demonstrable tumours. The films were obtained by serial exposures at intervals of 0.67 seconds and were studied from the aspects of the anatomy and blood flow after injection of contrast

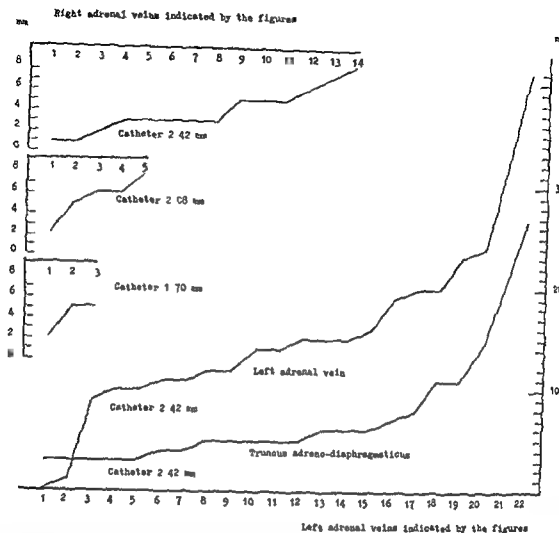


Fig 7 Diagram showing how the adrenal veins were catheterized. Each case that was catheterized is marked on the abscissas and the catheterizable lengths of the veins on the ordinates measured in mm. The whole length of the truncus adreno-diaphragmaticus could always be catheterized and is shown independently of the catheter length of the left adrenal vein proper.

only one adrenal vein and that this ran to the renal vein. JOHNSTONE however observed in one instance an accessory vein running to the veins in the renal capsule.

As regards the right side, the first three investigators stated that a single vein always ran between the adrenal gland and the vena cava. CLARK's and JOHNSTONE's observations differed. CLARK observed in seven instances another large vein running from the head of the gland to the vena cava, and JOHNSTONE found that in five instances the efferent vein opened into a liver vein and in one instance into a rudimentary vena cava on the right side located between the renal vein and

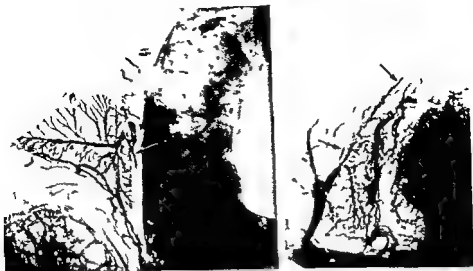


Fig 8 Two extraglandular veins running to the right adrenal vein and a vein in the ventral sulcus of the left adrenal gland (arrows) running to the efferent vein in the hilum. No other connections between intra- and extraglandular vessels are visible.

the atrium. The vena cava was of normal size on the left side. In two instances the adrenal vein was divided into two or three vessels respectively, opening into the vena cava. Only two veins emptied single into the vena cava, and one of them was only 2 mm wide. In the case in which three adrenal veins were present, the largest was 2.5 mm wide. In the other cases there was always a vein measuring at least 3 mm in width that ran from each adrenal gland.

Present investigation

Material. A series of 22 necropsy specimens were studied. These were taken from 11 female and 11 male bodies, from patients over 50 years of age who had died of cerebral or cardiac diseases. The anatomic studies were mainly carried out to investigate the direct venous communications between the large central veins of the adrenal glands and the vena cava together with its tributaries.

Films from the phlebographies previously carried out by the writer in 25 adrenal glands on the right side and 36 on the left side were also studied. These examinations were performed with a film changer, in patients with essential or renal hypertension and there were no complications or demonstrable tumours. The films were obtained by serial exposures at intervals of 0.67 seconds and were studied from the aspects of the anatomy and blood flow after injection of contrast

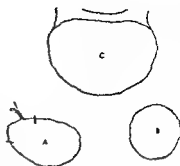


Fig 9 Transverse section of the vena cava (A), with the right adrenal vein marked in black. Its outlet was always located within the marked area on a level with the twelfth thoracic vertebra (C). The aorta is indicated by B.

medium within anastomosing extraglandular veins in close proximity to the adrenal glands before their communications with more distant vessels.

The contrast medium used was a modification of the method for microangiography described by IVERMARK *et coll* (1967). With all organs still in position, a suspension of barium sulphate, in which one part by weight of Mixobar (Kistner) had been mixed with three parts of water, was infused into the upper portion of the vena cava through the right atrium from a container placed about 60 cm above the body. Owing to leakage through the vena azygos and other paravertebral veins the mediastinum had to be ligated in advance directly caudal to the hilum of the lung as well as in the cranial portion of the mediastinum. Blood and coagula were removed as far as possible from the venous system by palpation, in most cases the inferior part of the vena cava was compressed by pressure from above. Infusion was continued for two hours. In the last fourteen necropsies, a procedure similar to LINDBOY's (1950) method was used in addition to the infusing process. The contrast medium was withdrawn from the large veins, a new barium suspension containing 20 g gum arabic and 30 g gelatine per 700 g suspension was added, and this was allowed to solidify for about 30 minutes. The intestine was then removed, and the other abdominal organs and retroperitoneal tissues together with the muscles and anterior portion of the vertebral bodies were taken out in one block and fixed in 10 % formalin for one week. This gave specimens that were suitable for dissection in association with roentgen examinations. The liver, stomach, pancreas and spleen, except for the parts adjacent to the adrenal glands, were removed in each preparation before the studies were begun.

The preparations were roentgenographed at several stages of the work and between the examinations organs were removed approximately in the following order: (1) spinal column, (2) skeletal muscles, (3) remaining parts of the stomach, pancreas and spleen, (4) extracapsular tissue dorsal to the adrenal



Fig 10 A small hepatic vein and a right adrenal vein opening laterally into the vena cava through a 4 mm long common stem. The liver vein is cut off at the liver capsule (arrow). a) Ap view b) Axial view. Dorsal surface down wards.

glands and kidneys, (5) remaining parts of the liver parenchyma, (6) liver capsule, (7) extracapsular tissue ventral to the adrenal glands and kidneys, and (8) capsules of the adrenal glands, subcapsular veins, and kidneys.

In the early stages of the dissections the specimens were roentgenographed in a water bath. The films were obtained at a focal distance of 90 cm. Non-screen industrial film (CEA) without a grid was exposed with the small focal spot, using 50 to 40 kV and 800 to 100 mAs. At least three views were obtained at each roentgen examination, with adjustment for an increased stereoscopic effect with the tube angled 30° and 15° from the right and 15° from the foot end. The diameters of small veins were measured on the roentgen films with a micrometer screw and with a magnification of $\times 20$. After removal of the contrast mass, the width of the adrenal veins was investigated by introducing polythene catheters of sizes P.E. 240, 205 or 190 and with an outer diameter of 2.42, 2.08 or 1.70 mm. A note was made of the largest catheter that could be used and of how far it could be pushed in, measuring from the vena cava or the opening of the phrenic vein into the left adrenal vein.

The inner vena cava wall and renal veins were also investigated for possible outlets of undetected vessels (which were never found).

Before the barium infusions, trials had been made in about 10 necropsies, with infusion of polymerizing plastic, Quick 33, which sets in 20 to 30 minutes, depending on the amount of hardener added. As the venous filling obtained was not satisfactory, these experiments were not included in the present series.



Fig 11 Epinephro phlebography. The veins in the right adrenal are filled at the same time as those in a small liver lobe. Numerous anastomoses to other liver veins are visible as usual in the liver lobe. a) A p view. A large amount of contrast medium is concentrated to the liver lobe. b) Oblique view. The adrenal veins filled well after changing the position of the catheter.

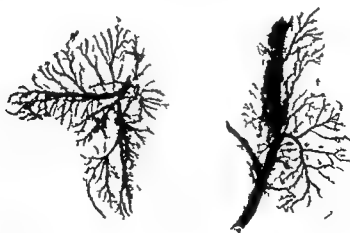


Fig 12 The venous system of both adrenal glands is filled out to the outermost parts of the alar raphe. The darker strip between the h lum in the head portion and the tail is the crest on the dorsal aspect.

Technical considerations A large number of veins of all sizes down to a diameter of 0.03 mm were well filled at all levels of the preparations, despite the presence of coagula in the large and medium sized vessels and notwithstanding that in the first eight cases the contrast medium had been partially emptied from these vessels when the specimens were removed. The veins could nevertheless be assessed satisfactorily, as a sufficient amount of barium had become attached to their walls. In the peripheral veins, the barium particles had become packed into a powdery mass owing to sedimentation, while the fluid in the suspension had passed on. This had already been observed during the infusion, when the peritoneal fluid gradually increased.

The roentgen examinations were a valuable aid during the dissection work, among other things because they gave information on whether vessels that had been dissected out continued within the adrenal glands or not. Because of their white colour, the contrast filled vessels were also easily distinguished in the necropsy studies.

Polymerizing plastic as a filling for the veins proved to have disadvantages and could not be used in the present investigation. Abrupt blocks and breaks in the continuity often occurred, even in relatively large vessels. Because of surface tension, it is probably difficult for a plastic material, which is insoluble in blood, to push past the clots that commonly occur in dorsally located veins and tend to occlude them during infusion.

Results

Position of the adrenal glands The left gland always lay near the upper medial portion of the kidney, close to its ventral tangent, and the head of the gland usually extended down to the cranial part of the renal hilum. The right gland was always located beside the liver and the vena cava, at the level of the twelfth thoracic to first lumbar vertebrae, irrespective of the kidney's position. Similar conditions have been reported by LINDVALL & SLEZAK (1969). In fifteen instances, the right adrenal glands were triangular, with sides of approximately equal lengths, but in seven the cranial side was short and the crest began near the inferior corner of the gland.

Efferent veins In all instances, only one efferent vein from the central venous system of each gland was observed. The left adrenal vein always opened into the left renal vein at a point 13 to 46 mm from the vena cava (Figs 5 and 6). The inferior phrenic vein opened into the renal vein in one instance and into the adrenal vein in all the others. All adrenal veins on the left side could be catheterized with a 2.42 mm catheter for a distance of 3 to 27 mm past the openings of the phrenic vein or of any other tributaries present. The truncus adreno-diaphragmaticus was 1 to 31 mm long (Fig. 7).



Fig 11 Epinephro phlebography. The veins in the right adrenal are filled at the same time as those in a small liver lobe. Numerous anastomoses to other liver veins are visible as usual in the liver lobe. a) Ap view. A large amount of contrast medium is concentrated to the liver lobe. b) Oblique view. The adrenal veins filled well after changing the position of the catheter.



Fig 12 The venous system of both adrenal glands is filled out to the outermost parts of the alar raphe. The darker strip between the hilum in the head portion and the tail is the crest on the dorsal aspect.



Fig 14 Concomitant veins around both adrenal glands. Central veins around an adenoma (arrow) (Vasa vasorum aortae are also visible)

forming a common stem with a liver vein, the outlet was located ventrally within that sector. A study of the phlebographic findings in previous publications revealed that the catheterized adrenal veins, two of which had common stems with a liver vein, always had their outlets within an area extending 1 cm cranial to, and 1.5 cm inferior to the twelfth rib (Mikaelsson 1969) (Fig 11).

The 2.42 mm catheter could on the right side be inserted for a distance of 1 to 8 mm in fourteen veins, while eight veins were too narrow to admit it. A 2.08 mm catheter passed in for 2 to 8 mm in five vessels, and in the other three only a 1.70 mm catheter could be pushed in for 2 to 5 mm (Fig 7).



Fig 15 Adenoma of the right adrenal gland in fig 14

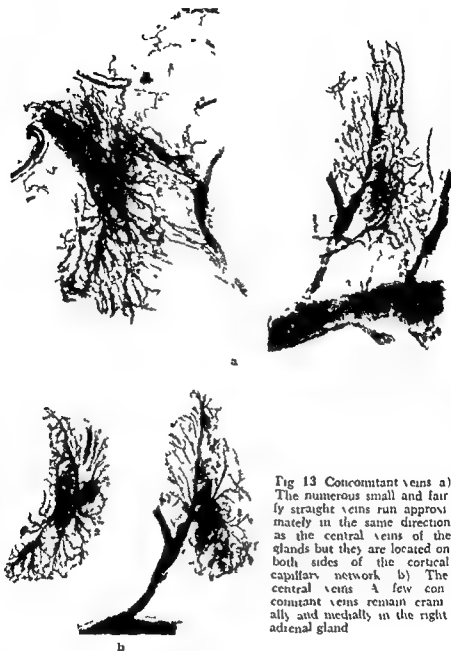


Fig 13 Concomitant veins a) The numerous small and fairly straight veins run approximately in the same direction as the central veins of the glands but they are located on both sides of the cortical capillary network b) The central veins A few concomitant veins remain cranially and medially in the right adrenal gland

On the right side, the efferent vein ran directly to the vena cava in 20 out of 22 necropsies (Figs 5, 6 and 8). In two instances, the right adrenal vein and a small hepatic vein had a common stem outside the adrenal and hepatic capsules for a distance of 4 mm and 1 mm respectively before reaching the vena cava (Figs 10, 18 and 20). All the efferent veins from the right adrenal glands opened 19 to 62 mm cranial to the right renal vein into the right dorsal quadrant of the vena cava wall (Figs 9 and 10). When the venous outflow took place through a vessel



a



b

Fig 17 a) Superficial veins that were cut at the site where they diverged from the surfaces of the adrenal glands b) Only central veins are visible, as well as one emissary vein (arrow)

In addition to the concomitant veins, a number of small and relatively large veins with a winding irregular course over the surface of the glands, and often located between the capsule and cortex, also filled with contrast medium. They often joined veins in the renal capsule, but sometimes connected up with central vein branches of the adrenal gland, they then had the appearance of emissary veins (Figs 5, 6 and 17)

As has also been reported by SUDANOW & SSAPIN (1968) superficial veins were observed at the bottom of sulci in eleven glands, in most instances in the ventral groove of the left gland. They had extraglandular tributaries, and in six instances had direct communications with the efferent vein in or slightly before the opening into the hilum (Figs 8, 18 and 19)



Fig 16 A large vein in the dorsal groove lateral to the crest in the left adrenal gland (arrow) Part of the vein has been removed. Concomitant veins are seen between the gland and the kidney

Central veins A large number of the central veins, down to a diameter of 0.03 mm, filled with contrast medium. In six glands however the filling was incomplete, and seven had ruptured centrally. The veins in the others could be followed to a point 1 to 2 mm from the edges of the glands. This corresponds to the inner surface of the cortex at its transition between the ventral and dorsal surfaces of the gland (Figs 8, 10, 12, 13, 16 and 19). Anastomoses of the type described by SHIDANOW & SSAPIN (1968) were seen in thirteen glands, with one to four in each.

Peripheral veins A large number of small venae comitantes outside the adrenal glands always filled with contrast medium. They were all of relatively the same diameter, about 0.1 mm, and were either comparatively straight, or arched. They radiated out from the glands in the same direction as the large branches of the central veins, although most of them were not continuous with those vessels. In the head of the left gland for instance they ran in an obliquely caudal direction, while in the body and tail they took an increasingly oblique, cranial course. The arrangement was more or less similar in the right gland. Some of them were directly continuous with small central veins, but most of them began at the surface of the gland (Figs 13, 14, 16 and 18).

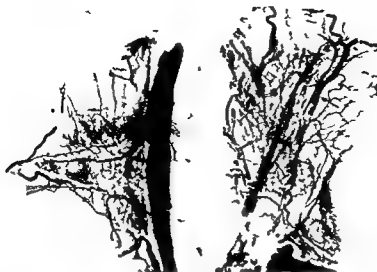


Fig 18 A right adrenal vein with a 1 mm long stem in common with a small left adrenal vein. A large vein in the dorsal sulcus of the left gland (\rightarrow). Several ventral capsule veins mostly in the ventral sulcus run to the efferent vein (\rightarrow)



Fig 19 Most extraglandular vessels are removed. Small ruptures in both glands same case as in Fig 18

Studies of the blood flow at phlebography These studies included the extra glandular veins before their anastomosis with large vessels outside the glands, in other words within a distance of about 1 cm from the glands. The flow of contrast medium was studied after injection. Only veins that had filled from within the adrenal glands or from their hilar regions were assessed.

The movements of the contrast medium in veins around the left adrenal gland could be assessed in twenty four instances, the flow was in the central direction in twenty three and towards the periphery in one (Fig 21). In a further eleven instances, the conditions could not be assessed, as the contrast medium sometimes thinned out and gave no indication of the direction of flow, or disappeared completely between two films, once no peripheral veins filled despite adequate filling of the central veins.

Assessment was possible on the right side in eighteen instances and the contrast medium had flowed centrally in all of them. The direction of flow could not be judged in a further three glands, and no veins were filled around four glands although the central veins had filled satisfactorily.

Discussion

Efferent veins All adrenal glands were found at the anatomic investigation to have a single draining vein running to the left renal vein or to the vena cava. In two instances, a right adrenal vein and a small hepatic vein had a short common stem. This finding may be compared with the phlebographic observations in which two adrenal glands on that side, out of 36, filled through a stem in common with a small hepatic vein. The result differs from the descriptions of other authors.

As regards the width of the efferent veins, JOHNSTONE, it is true, gave measurements but he did not state how his figures were reached nor where the measurements were taken. This information is of importance when the possibilities for catheterizing the vessels are being judged, as the width increases towards the outlet. As the circumference of the veins, in anatomic preparations at least, is seldom round, not even when they are filled, the width must be calculated by dividing the circumference of the lumen by π or by catheterizing with tubes of known diameters. As, in the present study, the width was investigated mainly to ascertain the possibility of catheterizing the veins at phlebography, the diameter of the tubes was limited to a maximum of 2.42 mm despite the fact that the vessels were in a number of cases wider than the catheter. This width corresponded to the size of the catheter, P.E. No. 240, used at the phlebographic examinations.

The largest catheter could in all cases be pushed past the opening of the phrenic vein into the adrenal vein proper on the left side. On the right side, it could be inserted in only fourteen out of twenty two adrenal veins while eight

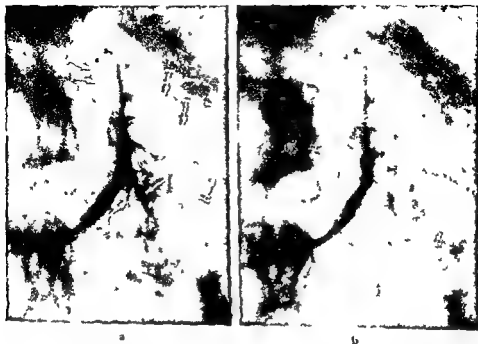


Fig 21 Studies of blood flow in a left adrenal gland a) During injection b) Immediately after termination of the injection The contrast medium flowing back in a central direction in both veins with a (→) and on side (↘) the gland The flow in a lateral vein (↗) could not be assessed

The right adrenal vein sometimes bends sharply just before it enters the vena cava. When this occurs, the catheter does not pass in as far as it otherwise reaches at catheterization. This is usually of no significance in the angiographic examination but it probably largely explains why blood is often more difficult to obtain from the right side than from the left. The opening of the catheter may come too close to the vessel wall with the result that a valvular effect arises. In the phlebographic series, 30 ml of blood could be withdrawn from the right adrenal gland for aldosterone determinations at 21 out of 36 catheterizations, while the same amount of blood was obtained from the left adrenal gland in all the twenty three cases examined by the modified technique which was used in part of the series.

Central veins The central venous system extends in the alar raphe to the edges of the gland where the 1 to 2 mm thick layers of cortex meet, and consequently the size and shape of the gland may be assessed at phlebography if the venous system has filled completely with contrast medium. The appearance differs from that usually seen when the vessels fill during arterial angiography. It then looks

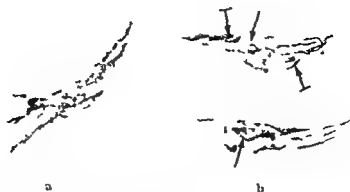


Fig. 20 a) Right adrenal gland in the dorsal position from the lateral side. Hepatic vein in axial projection. b) Section through both adrenal glands with dorsal surface downwards. Left gland uppermost. Central vein (→). Veins in ventral and dorsal sulci (↔). Same case as in figs 18 and 19.

veins were too narrow. At phlebography 36 catheterizations out of 51 had been successful. A statistical analysis using the chi square test revealed no significant differences between the series.

It is unlikely that the width of the veins in anatomic preparations differs from the *in vivo* width. Their muscle tissue is largely longitudinal (MARESC 1921, KUTSCHERA AICHBERGER 1922, DOBBIE & SYMINGTON 1966, and others), and probably has little effect on the width. Appreciable shrinking as a result of formalin fixing can hardly have occurred, as the fixation was of a low degree in the central parts of the preparations. The tissues in those parts were of normal consistency and colour. The probable explanation of the failures at catheterization is that the veins were sometimes too narrow to admit the catheter used at the phlebographic examination. The fact that adrenal veins may have a common stem with a liver vein is on the other hand of no particular importance. Even in those cases in which this was observed, the vein had its outlet within a small area in the right dorsal quadrant of the vena cava wall, on a level with the twelfth rib. In the roentgen studies the liver lobe did not conceal the adrenal gland in question. Should this occur, an alteration in the projection should be made. Phlebography could perhaps be carried out more often if smaller catheters were also available but in that event the difficulties at catheterization would increase. Not only is a finer catheter harder to manoeuvre in the vena cava which usually is fairly flat, but it is also more difficult to distinguish on the TV screen. If the tip alone were made narrower, there would be a greater risk of small intimal injuries and paravasal leakage of contrast medium. A movable inner catheter might give rise to uncontrollable tension irregularities between the two tubes. A catheter with an extra long, flexible tip might perhaps be tried however.

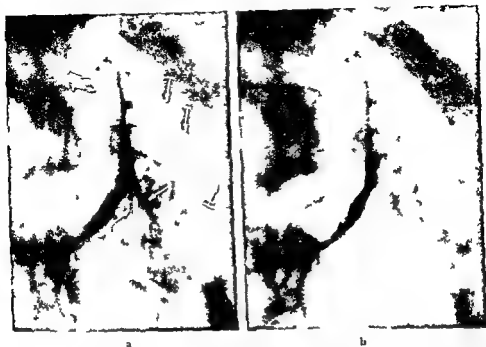


Fig. 21. Studies of blood flow in a left adrenal gland. a) During injection. b) Immediately after termination of the injection. The contrast medium flowing back in a central direction in both veins: then (→) and outside (↘) the gland. The flow in a lateral vein (↗) could not be assessed.

The right adrenal vein sometimes bends sharply just before it enters the vena cava. When this occurs, the catheter does not pass in as far as it otherwise reaches at catheterization. This is usually of no significance in the angiographic examination but it probably largely explains why blood is often more difficult to obtain from the right side than from the left. The opening of the catheter may come too close to the vessel wall, with the result that a valvular effect arises. In the phlebographic series, 30 ml of blood could be withdrawn from the right adrenal gland for aldosterone determinations at 21 out of 36 catheterizations, while the same amount of blood was obtained from the left adrenal gland in all the twenty-three cases examined by the modified technique which was used in part of the series.

Central veins. The central venous system extends in the alar raphe to the edges of the gland where the 1 to 2 mm thick layers of cortex meet, and consequently the size and shape of the gland may be assessed at phlebography if the venous system has filled completely with contrast medium. The appearance differs from that usually seen when the vessels fill during arterial angiography. It then looks

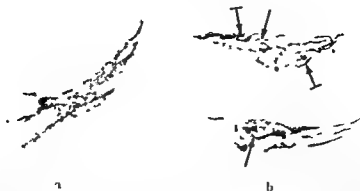


Fig 20 a) Right adrenal gland in the dorsal position, from the lateral side Hepatic vein in axial projection b) Section through both adrenal glands, with dorsal surface downwards Left gland uppermost Central vein (→) Veins in ventral and dorsal sulci (↔) Same case as in figs 18 and 19

veins were too narrow. At phlebography, 36 catheterizations out of 51 had been successful. A statistical analysis using the chi-square test revealed no significant differences between the series.

It is unlikely that the width of the veins in anatomic preparations differs from the *in vivo* width. Their muscle tissue is largely longitudinal (MARESCU 1921, KUTSCHERA-AICHBERGEN 1922, DOBBIE & SYMINGTON 1966, and others), and probably has little effect on the width. Appreciable shrinking as a result of formalin fixing can hardly have occurred, as the fixation was of a low degree in the central parts of the preparations. The tissues in those parts were of normal consistency and colour. The probable explanation of the failures at catheterization is that the veins were sometimes too narrow to admit the catheter used at the phlebographic examination. The fact that adrenal veins may have a common stem with a liver vein is on the other hand of no particular importance. Even in those cases in which this was observed, the vein had its outlet within a small area in the right dorsal quadrant of the vena cava wall, on a level with the twelfth rib. In the roentgen studies the liver lobe did not conceal the adrenal gland in question. Should this occur, an alteration in the projection should be made. Phlebography could perhaps be carried out more often if smaller catheters were also available but in that event the difficulties at catheterization would increase. Not only is a finer catheter harder to manoeuvre in the vena cava, which usually is fairly flat, but it is also more difficult to distinguish on the TV screen. If the tip alone were made narrower, there would be a greater risk of small intimal injuries and paravasal leakage of contrast medium. A movable inner catheter might give rise to uncontrollable tension irregularities between the two tubes. A catheter with an extra long, flexible tip might perhaps be tried however.



Fig. 71. Studies of blood flow in a left adrenal gland. a) During injection. b) Immediately after termination of the injection. The contrast medium flowing back in a central direction in both veins, in (\rightarrow) and outside (\leftarrow) the gland. The flow in a lateral vein (\leftarrow) could not be assessed.

The right adrenal vein sometimes bends sharply just before it enters the vena cava. When this occurs, the catheter does not pass in as far as it otherwise reaches

from the right side than from the left. The opening of the catheter may come too close to the vessel wall, with the result that a valvular effect arises. In the phlebographic series, 30 ml of blood could be withdrawn from the right adrenal gland for aldosterone determinations at 21 out of 36 catheterizations, while the same amount of blood was obtained from the left adrenal gland in all the twenty-three cases examined by the modified technique which was used in part of the series.

Central veins. The central venous system extends in the alar raphe to the edges of the gland where the 1 to 2 mm thick layer of cortex meets, and consequently the size and shape of the gland may be assessed at phlebography if the venous system has filled completely with contrast medium. The appearance differs from that usually seen when the vessels fill during arterial angiography. It then looks

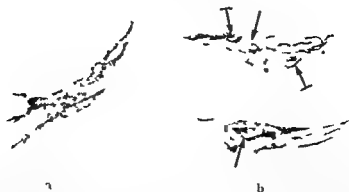


Fig 20 a) Right adrenal gland in the dorsal position from the lateral side. Hepatic vein in axial projection. b) Section through both adrenal glands with dorsal surface downwards. Left gland uppermost. Central vein (→). Veins in ventral and dorsal sulci (↔). Same case as in figs 18 and 19.

veins were too narrow. At phlebography, 36 catheterizations out of 51 had been successful. A statistical analysis using the chi square test revealed no significant differences between the series.

It is unlikely that the width of the veins in anatomic preparations differs from the *in vivo* width. Their muscle tissue is largely longitudinal (MARESCHI 1921, KUTSCHERA-AICHBERGEN 1922, DOBBIE & SYMINGTON 1966, and others), and probably has little effect on the width. Appreciable shrinking as a result of formalin fixing can hardly have occurred, as the fixation was of a low degree in the central parts of the preparations. The tissues in those parts were of normal consistency and colour. The probable explanation of the failures at catheterization is that the veins were sometimes too narrow to admit the catheter used at the phlebographic examination. The fact that adrenal veins may have a common stem with a liver vein is on the other hand of no particular importance. Even in those cases in which this was observed, the vein had its outlet within a small area in the right dorsal quadrant of the vena cava wall, on a level with the twelfth rib. In the roentgen studies the liver lobe did not conceal the adrenal gland in question. Should this occur, an alteration in the projection should be made. Phlebography could perhaps be carried out more often if smaller catheters were also available but in that event the difficulties at catheterization would increase. Not only is a finer catheter harder to manoeuvre in the vena cava, which usually is fairly flat, but it is also more difficult to distinguish on the TV screen. If the tip alone were made narrower, there would be a greater risk of small intimal injuries and paravasal leakage of contrast medium. A movable inner catheter might give rise to uncontrollable tension irregularities between the two tubes. A catheter with an extra long, flexible tip might perhaps be tried however.

buffer against the movements of the diaphragm, might have some functional connection with the adrenal glands, whether for instance it serves as a raw material depot for hormone production. If this were so, transportation would then take place through the extraglandular veins. This would presuppose some form of portal circulation. A similar intraglandular arrangement of portal type between the reticulate zone and the cortical cuffs which enclose many veins in the medulla (Fig. 4) has been described by VELICAN (1947).

Conclusions

1 Infusion of diluted Mixobar in the vena cava produced intense contrast filling of its tributaries down to a diameter of 0.03 mm.

2 Among 22 adrenal glands on the right side and the same number on the left, drainage occurred through a single vein in every instance. In two cases the right adrenal vein had a terminal stem in common with a small hepatic vein, in the others the vein ran the usual course to the vena cava or left renal vein.

3 The right adrenal vein was in 14 instances catheterized with a catheter of 2.42 mm diameter. This size was too large for the other eight glands. The right adrenal vein could be catheterized in approximately the same number of cases at epinephro-phlebography. A probable cause of unsuccessful catheterizations was that the adrenal vein was too narrow to admit this catheter.

4 The fact that an adrenal vein has a short stem in common with a small hepatic vein is of no particular importance. It filled through the common stem, which opened in the usual way into the right posterior quadrant of the vena cava, at the level of the twelfth rib.

5 The venous system of the adrenal glands had the same appearance in anatomic specimens as at epinephro-phlebography. The contrast filled veins permitted detailed assessment of the size and shape of the glands.

SUMMARY

The adrenal venous system was studied in twenty two post mortem cases. A single draining vein was found to run from the right gland to the vena cava and from the left gland to the left renal vein. Eight veins were however too narrow for catheters of the size used in a previous epinephro-phlebographic series in which the catheterizations failed to the same extent. The right adrenal vein and a hepatic vein had sometimes a terminal stem in common but this did not prevent phlebography. The intraglandular veins appeared similar in both series.

ZUSAMMENFASSUNG

Das Venensystem der Nebennieren wurde in 22 post mortem Fällen untersucht. Es wurde gefunden, dass eine einzelne ableitende Vene von der rechten Nebenniere zur Vena cava und von der linken Nebenniere zur linken Nierenvene führt. Acht Venen waren jedoch zu eng für die Katheter derselben Grösse wie sie bei einer vorhergehenden Nebennieren-

more like an arrowhead, with the contrast medium visible mainly at the edges on the cranial aspect, notwithstanding that the margins are thinnest at that site. Contrast filling thus takes place most easily in those parts of the gland that consist solely of cortex. The information provided by arterial angiography may be increased if the examination is performed under increased pulmonary pressure and after injection of adrenalin, as the adrenal arteries are relatively insensitive to this hormone which contracts other vessels (RIGBY & ROTHBERGER 1927, KAHN 1967, LINDVALL & SIZZAK 1969). However, the true configuration of the adrenal glands may be assessed with certainty only during a distinct venous phase, and such a phase is best obtained by phlebography.

Peripheral veins. The venous system outside the adrenal glands consists partly of vessels in direct contact with the central veins. They may be demonstrated at phlebography and as a rule can be distinguished from the central vessels. This applies also to the vessels in sulci, especially if different projections are used. The flow of the contrast medium could be assessed in 42 out of 61 glands in the phlebographic material, it flowed centrally in 41 instances and towards the periphery in only one case. These observations applied to patients with essential or renal hypertension examined in the supine position.

In the anatomic studies, many veins were seen running for long distances over the surface of the adrenal glands between the capsule and cortex. This was true both for the veins in sulci, some of which opened into the central veins, and for the other veins that ran past the adrenal glands in different directions and could not be demonstrated at phlebography. Like most of the concomitant veins, they were located on the other side of the cortical capillary network.

The arrangement is difficult to explain. In few other parts of the body have veins been encountered that run for a similar distance through parenchymatous organs or that have had this type of contact with their surface without branches to the glands possible to detect macroscopically. Another feature should also be mentioned, namely the thick layer of fat that surrounds the kidneys and especially the adrenal glands. A fatty capsule of this nature does not envelop other organs of the body, nor is it found around other hormone-producing, lipid-bearing glands. Because of the crest, the dorsal, fat-facing surface of the adrenal glands is large, and the fat is thickest on the dorsal aspect. When during adolescence the adrenal glands develop and the venous musculature becomes stronger (HEINIVAARA 1953/54), this fat increases in thickness (VELICAN & VELICAN 1949).

As both the adrenal glands lie well-protected against trauma behind ribs, transverse processes of the vertebrae, and thick layers of muscle, the fat would seem to be unnecessary as a mechanical protection. It is perhaps not unreasonable to wonder whether the periglandular fat, in addition to its probable function as a

- FERGUSON J S The veins of the adrenal *Amer J Anat* 5 (1906) 63
- GAGNON R The venous drainage of the human adrenal gland *Rev canad Biol* 14 (1956), 350
- The arterial supply of the human adrenal gland *Rev canad Biol* 16 (1957), 421
- FRANCINI D, FANTINI B and ZANOLI P G Possibilit  offerte dalla flebografia renale allo
-
- Sur la vascularisation de la graisse interreno-surr nale chez l'homme *C R Soc Biol (Paris)* 73 (1912) 513
- Contribution   l' tude morphologique des art res des capsules surr nales chez l'homme *J Anat (Paris)* 49 (1913), 269
- HEINIVAARA O On the structure of the human suprarenal vein with reference to structural changes in hypertension *Ann Med intern Fenn* 43 (1953/54) Suppl Nos 14-20
- HEWARIK B, ENSTROM T and LAGERCR N C The vasculature of the developing and mature human adrenal gland *Acta paediat scand* 56 (1967) 601
- JOHNSTONE F R C The suprarenal veins *Amer J Surg* 94 (1957) 615
- KARY P C The epinephrine effect in selective renal angiography *Radiology* 85 (1965), 401
- Selective angiography of the inferior phrenic arteries *Radiology* 88 (1967) 1
- K TCHERA AICHBERGEN H Nebennierenstudien Frankfurt *Z Path* 28 (1922) 262
- LINDBO M Arteriosclerosis and arterial thrombosis in the lower limb A roentgenological study *Acta radiol* (1950) Suppl No 80
- LINDVALL A and SLEZAK P Arteriography of the adrenals *Radiology* 92 (1962) 999
- MARECH R Die Venenmuskulatur der menschlichen Nebenniere und ihre funktionelle Bedeutung *Wien klin Wochr* 34 (1921) 44
- MERALIV R J The arterial supply of the suprarenal gland *Anat Rec* 144 (1962), 359
- and EGER S A The adrenal venous system in man *J int Coll Surg* 35 (1961) 572
-
- MINI 6 (1967) 348
- Epinephro-phlebography in two cases of Conn's syndrome *Acta radiol Diagnosis* 7 (1968) 410
- Epinephro phlebography of benign tumours. *Acta radiol Diagnosis* 11 (1969) 129
- MINO G La vascularizzazione della surrenale umana (In Italian) *Chir ital* 9 (1957) 437
- OTTAVIANI G Sulla vascularizzazione venosa delle ghiandole surrenali dell'uomo (In Italian) *Arch ital Anat Embriol* 36 (1936) 173
- R CHER R und ROTHBERGER C J Die Pharmakologie der Gef sse und des Kreislaufes *Handb norm pathol Physiol* 7 (1927) 2
- SHIRANOW D A und SAFFIN M R Die Nebennierenvenen als Abflusswege der Katecholamine *Z mikr anat Forsch* 78 (1968) 187
- VELICAY C Le baignage vasculaire cortico-medullaire de la surrenale de l'homme *Ann Endocr* 8 (1947) 495
- et VELICAY H Le tissu adipeux p risurr nal *Arch Anat micr Morph exp* 38 (1949) 38
- WINKLER S S and KARY P C Pharmacologic aids in adrenal angiography *Invest Radiol* 2 (1967) 48

Phlebographie Serie verwendet wurden und bei der die Kathetersierung im gleichen Ausmass missglückte. Die rechte Nebennierenvene und eine Lebervene hatten in einigen Fällen einen gemeinsamen terminalen Stamm, was aber die Phlebographie nicht unmöglich machte. Die intraglandulären Venen traten in beiden Serien in ähnlicher Weise hervor.

RÉSUMÉ

L'auteur a étudié sur vingt deux sujets d'autopsie le système veineux surrenalien. Il a trouvé une veine de drainage unique allant de la surrenale droite à la veine cave et de la surrenale gauche à la veine rénale gauche. Cependant huit veines étaient de calibre trop petit pour les cathétères utilisés dans une série précédente de phlébographies des surrenales. Série dans laquelle le cathétérisme avait échoué dans la même proportion de cas. Dans certains cas la veine surrenale droite et une veine hépatique avaient un tronc terminal commun mais ceci n'empêche pas la phlébographie. Les veines intra glandulaires avaient le même aspect dans ces deux séries.

REFERENCES

- ABRAMS H, BOIJSEN E and BORGSTROM K E Effect of epinephrine on the renal circulation. Angiographic observations. *Radiology* 79 (1962), 911
- ANSON B J and CAULDWELL E W The pararenal vascular system. A study of 425 anatomical specimens. *Quart Bull Northw Univ med Sch* 21 (1947) 320
- — PICK J W and BEATON L E The blood supply of the kidney suprarenal gland and associated structures. *Surg Gynec Obstet* 84 (1947) 313
- BADELLINO F, MASSA G, ROSOTTO P e TRINCIGIERI P Architettura arteriosa e venosa capsulare ed intraghiandolare del surrene umano (In Italian) *Minerva chir* 14 (1959) 347
- BARGMANN W Über den Bau der Nebennierenvenen des Menschen und der Säugetiere. *Z Zellforsch* 17 (1933) 118
- BOBROVA G E Structural aspects of the venous bed of the adrenal gland in man. *Trudy Yubilenoi Nauchnoi Konferentsii Parvysakchennoi Pamyati Prof G M Josifova (Voronezh)* (1965), 26
- BOTTINI A C Anatomía descriptiva de las capsulas surrenales (In Spanish) *Rev Asoc méd argent* 60 (1946) 573
- BROMAN I Människans utveckling före födselen (In Swedish) C W K Gleerups förlag Lund 1927
- VAN BUCHHEM F S P, DOORENHUIS H and ELINGS H S Conn's syndrome caused by adrenal cortical hyperplasia. pathogenesis of the signs and symptoms. *Acta endocr (Kbh)* 23 (1956), 213
- BUSCH W Die arterielle Gefäßversorgung der Nebenniere zugleich ein Beitrag zur Anatomie der Nebenniere. *Z mikr anat Forsch* 6 (1955) 159
- CLARK K The blood vessels of the adrenal gland. *J roy Coll Surg Edinb* 4 (1958/59) 257
- COSTA A e SEVERI L Istologia e significato fisiopatologico del sistema venoso delle capsule surrenali (In Italian) *Sperimentale* 90 (1936) 321
- DOBBIE J W and SYMINGTON T The human adrenal gland with special reference to the vasculature. *J Endocr* 34 (1966) 479
- EKSTROM T, IVERMARK B and LAGERGREN C The vasculature of the adrenal gland in neoplasia and hyperplasia. an angiographic and micro angiographic study. *Virchows Arch path Anat* 343 (1968), 189

Case reports

Case 1 Woman, aged 44, who since the age of 13 had been on insulin for diabetes mellitus. Long history of left otitis media, occasionally acute. She suddenly developed pain in the neck and left ear, with raised temperature ESR 136 mm/h, normal cerebrospinal fluid. Roentgen examination revealed a diffuse retropharyngeal soft tissue swelling but normal osseous structures (Fig 1a). A week later, a peritonsillar abscess was incised. Cultures were negative and the symptoms gradually receded.

Severe cervical symptoms reappeared about 7 weeks later. The cervical spine was rigidly fixed but no abnormal neurologic signs were apparent. ESR was 133 mm/h, the anti-staphylolysin titre was markedly elevated (26 IU). Subsequent roentgen examination disclosed destruction of the base of the odontoid process and a larger retropharyngeal soft tissue swelling (Fig 1b). Biopsy of the retropharyngeal region indicated chronic unspecific inflammation. A Glisson sling relieved the pain.

Tonsillectomy was performed about 4 weeks later. During the following months the symptoms remained unchanged and all movements of the cervical spine were resisted. ESR was between 40 and 60 mm/h. Roentgen examination about 6 weeks after tonsillectomy revealed complete destruction of the odontoid process and erosion of the anterior arch of the atlas.

About 2 months later, the pain in the neck increased and the ESR rose. Further biopsy of the epipharynx showed inflammation of an unspecific nature. There was no evidence of tuberculosis.

The patient was re-admitted to hospital 3 months later, complaining of pain and stiffness of the neck, loss of taste perception and difficulty in pronouncing complicated words. Movement of the cervical spine was markedly decreased with paralysis of the glossopharyngeal and hypoglossal nerves but no abnormalities of the extremities were present. ESR was between 50 and 70 mm/h, white blood cell count 8000. Cerebrospinal fluid count 1000 white blood cells (916 polymorphonuclear and 84 mononuclear), Pandy ++, Widal +. Cultures were negative.

Roentgen examination revealed complete absence of the odontoid process, destruction of the right atlanto-axial joint and right sided subluxation of the atlas on the axis. Sclerosis of the clivus and thickening of the floor of the sphenoidal sinus were present. The retropharyngeal soft tissues which at the first examination were diffusely thickened had become narrower distally and formed a localized expansion in front of the atlas and axis (Fig 1c and d). The patient was fitted with a collar and received large doses of streptomycin and penicillin for two to three months. She was discharged after four weeks in hospital. She gradually improved and eventually returned to work.

The patient was seen at control examination seven years after recovery. There was some residual cervical stiffness and limitation of movements. The anti-staphylolysin titre was normal (0.5 IU). Roentgen examination disclosed bony ankylosis between the atlas and the axis (Fig 1e and f).

Case 2 Man aged 43 with history of peritonsillar abscesses, suddenly developed pain and stiffness in the neck, he consulted a private practitioner. The symptoms became worse but roentgen examination a few weeks later disclosed no noteworthy changes in the cervical spine (Fig 2a).

The patient was admitted to hospital 6 weeks later. The cervical spine was fixed in slight flexion and right rotation. The mucous membranes of the pharynx were red. The submandibular lymph nodes were enlarged and lymph nodes could also be palpated distal

DESTRUCTION OF THE ODONTOID PROCESS DUE TO ATLANTO-AXIAL PYOGENIC SPONDYLITIS

by

S AHIBACK and S COLLERT

Absence of the odontoid process is rare. Most of the cases published have been considered to be congenital malformations. HARLEY (1962) found 26 such cases in the literature and added one case of his own, GWINN & SMITH (1962) reported 22 cases from the literature, and four cases of their own. A few cases in which the odontoid process disappeared between two roentgen examinations have recently been reported. The absorption of the odontoid process was interpreted as a tuberculous manifestation in a case described by GWINN & SMITH, and as a *post traumatic phenomenon in the cases of FREIBERGER et coll* (1965) and FIELDING (1965).

Pyogenic atlanto-axial osteomyelitis has been described in the literature. ODELBORG-JOHNSON (1931) reported a case of unilateral arthritis, FRANK (1944) one with a pathologic fracture of the odontoid process, and LEACH et coll (1967) a case with small erosions in the odontoid process and the anterior arch of the atlas. The following two cases of pyogenic atlanto-axial osteomyelitis with complete disappearance of the odontoid process appear to be the first ones to have been reported.

Submitted for publication 26 September 1969

Case reports

Case 1 Woman, aged 44, who since the age of 13 had been on insulin for diabetes mellitus. Long history of left otitis media, occasionally acute. She suddenly developed pain in the neck and left ear, with raised temperature ESR 136 mm/h, normal cerebrospinal fluid. Roentgen examination revealed a diffuse retropharyngeal soft tissue swelling but normal osseous structures (Fig 1a). A week later, a peritonsillar abscess was incised. Cultures were negative and the symptoms gradually receded.

Severe cervical symptoms reappeared about 7 weeks later. The cervical spine was rigidly fixed but no abnormal neurologic signs were apparent. ESR was 133 mm/h, the anti-staphylolysin titre was markedly elevated. Roentgen examination disclosed destruction of the base of the odontoid tissue swelling (Fig 1b). Biopsy of the retropharyngeal soft tissue showed inflammation. A Glisson sling relieved the pain.

Tonsillectomy was performed about 4 weeks later. During the following months the symptoms remained unchanged and all movements of the cervical spine were resisted. ESR was between 40 and 60 mm/h. Roentgen examination about 6 weeks after tonsillectomy revealed complete destruction of the odontoid process and erosion of the anterior arch of the atlas.

About 2 months later, the pain in the neck increased and the ESR rose. Further biopsy of the epipharynx showed inflammation of an unspecific nature. There was no evidence of tuberculosis.

The patient was re-admitted to hospital 3 months later, complaining of pain and stiffness of the neck, loss of taste perception and difficulty in pronouncing complicated words. Movement of the cervical spine was markedly decreased, with paralysis of the glossopharyngeal and hypoglossal nerves, but no abnormalities of the extremities were present. ESR was between 50 and 70 mm/h, white blood cell count 8000. Cerebrospinal fluid count 1000 white blood cells (916 polymorphonuclear and 84 mononuclear), Pandy ++, Widal +. Cultures were negative.

Roentgen examination revealed complete absence of the odontoid process, destruction of the right atlanto-axial joint and right sided subluxation of the atlas on the axis. Sclerosis of the clivus and thickening of the floor of the sphenoidal sinus were present. The retropharyngeal soft tissues which at the first examination were diffusely thickened, had become narrower distally and formed a localized expansion in front of the atlas and axis (Fig 1, c and d). The patient was fitted with a collar and received large doses of streptomycin and penicillin for two to three months. She was discharged after four weeks in hospital. She gradually improved and eventually returned to work.

The patient was seen at control examination seven years after recovery. There was some residual cervical stiffness and limitation of movements. The anti-staphylolysin titre was normal (0.5 IU). Roentgen examination disclosed bony ankylosis between the atlas and the axis (Fig 1 e and f).

Case 2 Man, aged 43, with history of peritonsillar abscesses suddenly developed pain and stiffness in the neck, he consulted a private practitioner. The symptoms became worse but roentgen examination a few weeks later disclosed no noteworthy changes in the cervical spine (Fig 2a).

The patient was admitted to hospital 11 weeks later. The cervical spine was fixed in slight flexion and right rotation. The mucous membranes of the pharynx were red. The submandibular lymph nodes were enlarged and lymph nodes could also be palpated distal

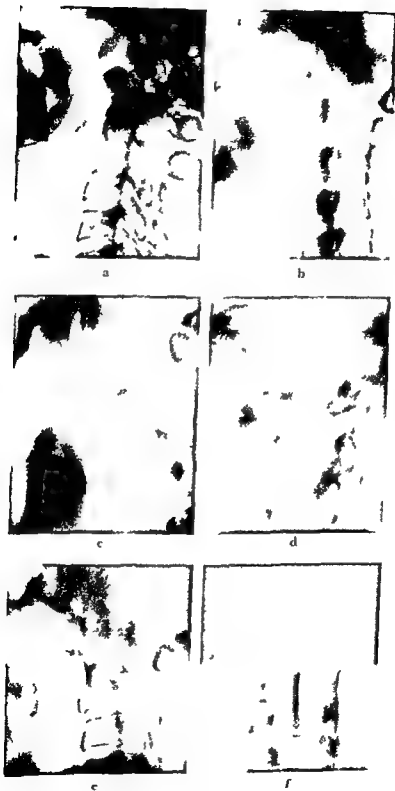


Fig. 1 (for legend see opposite page)

to the left mastoid process. ESR was raised, from 7 mm/h on admission to 110 mm/h one week later. The white blood cell count was 7900, the differential count showed no noteworthy change. Electrophoresis showed some increase of alpha 1 and alpha 2 globulin. The anti streptolysin titre (200 IU) and the anti staphylolysin titre (10 IU) were normal. The tuberculin test was negative.

Roentgen examination including tomography revealed complete destruction of the odontoid process, left atlanto-axial arthritis and diffuse swelling of the retropharyngeal soft tissues above the larynx. The atlas was subluxated to the right as well as anteriorly and caudally on the axis (Fig 2b). Roentgen examinations of the skull, chest, thoracic and lumbar spine, pelvis and the hip joints were negative. Cytologic examination of biopsy material from a lymph node showed unspecific inflammation. The retropharyngeal space and the left atlanto-axial joints were punctured under fluoroscopy but no material could be withdrawn with a fine gauge needle.

The patient was treated with cloxacillin per os and Crutchfield traction and finally the atlas and the axis were joined posteriorly with wire and autologous bone grafts. The patient improved rapidly and was discharged from hospital.

Roentgen examination at control 5 weeks later demonstrated that the retropharyngeal soft tissues were less prominent (Fig 2c). He returned to work 2 months later and 2 months after this was free of symptoms except for some limitation of cervical movements. Roentgen examination demonstrated almost complete absence of the odontoid process and bony ankylosis of the left atlanto-axial joint (Fig 2, d and e).

Discussion

The history and the course of the disease in these two cases were similar. The odontoid process gradually disappeared and unilateral atlanto-axial and subluxation could be demonstrated. Both patients had retropharyngeal soft tissue swellings, and the ESR was markedly elevated. Both patients recovered with only some limitation of movement of the cervical spine. The odontoid process remained absent at control examinations, in Case 1 no less than 7 years.

Absence of the odontoid process has usually been considered to be congenital. Trauma has been advanced by FREIBERGER et coll (1965) and by FIELDING (1965) as the cause for disappearance of the process. FREIBERGER et coll described a girl aged 2 1/2 years who had a large recent al soft tissue light trauma. After about

Fig. 1 (see on)

thickened floor of sphenoid sinus c) and d) Frontal and lateral tomograms 7 years after recovery Bony bridge between the anterior arch of atlas and body of the axis bony ankylosis of both intervertebral joints regression of the retropharyngeal soft tissue swelling and of the sclerotic of the clivus



Fig. 1 (for legend see opposite page)

to the left mastoid process. ESR was raised from 7 mm/h on admission to 110 mm/h one week later. The white blood cell count was 7900; the differential count showed no noteworthy change. Electrophoresis showed some increase of α_1 and α_2 globulin. The anti-streptolysin titre (200 IU) and the anti-staphylolysin titre (10 IU) were normal. The tuberculin test was negative.

Roentgen examination including tomography revealed complete destruction of the odontoid process, left atlanto-axial arthritis and diffuse swelling of the retropharyngeal soft tissues above the larynx. The atlas was subluxated to the right as well as anteriorly and caudally on the axis (Fig. 2b). Roentgen examinations of the skull, chest, thoracic and lumbar spine, pelvis and the hip joints were negative. Cytologic examination of biopsy material from a lymph node showed unspecific inflammation. The retropharyngeal space and the left atlanto-axial joints were punctured under fluoroscopy but no material could be withdrawn with a fine gauge needle.

The patient was treated with cloxacillin per os and Crutchfield traction and finally the atlas and the axis were joined posteriorly with wire and autologous bone grafts. The patient improved rapidly and was discharged from hospital.

Roentgen examination at control 5 weeks later demonstrated that the retropharyngeal soft tissues were less prominent (Fig. 2c). He returned to work 2 months later and 2 months after this was free of symptoms except for some limitation of cervical movements. Roentgen examination demonstrated almost complete absence of the odontoid process and bony ankylosis of the left atlanto-axial joint (Fig. 2, d and e).

Discussion

The history and the course of the disease in these two cases were similar. The odontoid process gradually disappeared and unilateral atlanto-axial and subluxation could be demonstrated. Both patients had retropharyngeal soft tissue swellings, and the ESR was markedly elevated. Both patients recovered with only some limitation of movement of the cervical spine. The odontoid process remained absent at control examinations, in Case 1 no less than 7 years.

Absence of the odontoid process has usually been considered to be congenital. Trauma has been advanced by FREIBERGER et coll (1965) and by FIELDING (1965) as the cause for disappearance of the process. FREIBERGER et coll described a girl, aged 2 1/2 years, who had a large retropharyngeal soft tissue swelling but otherwise no roentgen changes after comparatively slight trauma. Five months later the odontoid process had completely disappeared. After about

widening of retropharyngeal space 3 months after onset (c) and d) Frontal tomograms showing complete absence of the odontoid process with

the axis. Localized expansion of the upper retropharyngeal space (a) and to the right on thickened floor of sphenoid sinus (b) and f) Frontal and lateral tomograms 7 years after recovery. Bony bridge between the anterior arch of atlas and body of the axis, bony ankylosis of both intervertebral joints, regression of the retropharyngeal soft tissue swelling and of the sclerosis of the clivus.



Fig. 1 (for legend see opposite page)

to the left mastoid process ESR was raised, from 7 mm/h on admission to 110 mm/h one week later. The white blood cell count was 7900; the differential count showed no noteworthy change. Electrophoresis showed some increase of α_1 and α_2 globulin. The anti streptolysin titer (200 IU) and the anti staphylococcal titer (10 IU) were normal. The tuberculin test was negative.

Röntgen examination including tomography revealed complete destruction of the odontoid process, left atlanto-axial arthritis and diffuse swelling of the retropharyngeal soft tissues above the larynx. The atlas was subluxated to the right as well as anteriorly and caudally on the axis (Fig. 2b). Röntgen examinations of the skull, chest, thoracic and lumbar spine, pelvis and the hip joints were negative. Cytologic examination of biopsy material from a lymph node showed unspecific inflammation. The retropharyngeal space and the left atlanto-axial joints were punctured under fluoroscopy but no material could be withdrawn with a fine gauge needle.

The patient was treated with cloxacillin per os and Crutchfield traction and finally the atlas and the axis were joined posteriorly with wire and autologous bone grafts. The patient improved rapidly and was discharged from hospital.

Röntgen examination at control 5 weeks later demonstrated that the retropharyngeal soft tissues were less prominent (Fig. 2c). He returned to work 2 months later and 2 months after this was free of symptoms except for some limitation of cervical movements. Röntgen examination demonstrated almost complete absence of the odontoid process and bony ankylosis of the left atlanto-axial joint (Fig. 2, d and e).

Discussion

The history and the course of the disease in these two cases were similar. The odontoid process gradually disappeared and unilateral atlanto-axial and subluxation could be demonstrated. Both patients had retropharyngeal soft tissue swellings, and the ESR was markedly elevated. Both patients recovered with only some limitation of movement of the cervical spine. The odontoid process remained absent at control examinations, in Case 1 no less than 7 years.

Absence of the odontoid process has usually been considered to be congenital. Trauma has been advanced by FREIBERGER et coll (1965) and by FIELDING (1965) as the cause for disappearance of the process. FREIBERGER et coll described a girl aged 2 1/2 years who had a minor retropharyngeal soft tissue swelling after comparatively slight trauma which disappeared. After about

widening of retropharyngeal space 3 months after onset. Complete absence of the odontoid process with bony defects at the right atlanto-axial joint; the atlas is displaced forwards and to the right on the axis. Localized expansion of the upper retropharyngeal space, sclerosis of clivus, and thickened floor of sphenoid sinus (e) and f). Frontal and lateral tomograms 7 years after recovery. Bony bridge between the anterior arch of atlas and body of the axis, bony ankylosis of both intervertebral joints, regression of the retropharyngeal soft tissue swelling and of the sclerosis of the clivus.

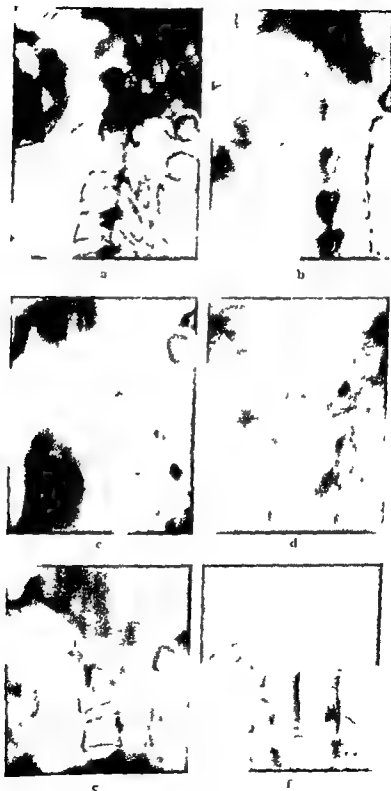


Fig 1 (for legend see opposite page)

to have been inflammatory rather than traumatic in nature. There was no history of trauma in our cases.

Rheumatoid arthritis may give rise to erosions of bone and to a pathologic fracture of the odontoid process (MARTIN & BOLE 1968). The process is usually affected only in advanced cases in which there are other manifestations of the disease. There is no report of complete destruction of the odontoid process in such cases. GUINN & SMITH (1962) stated that their case was the first one described of the disappearance of the odontoid process. The patient was a girl, aged 4 1/2 years, with areas of rarefaction in the odontoid process, seven years later the process had completely disappeared. The authors considered that tuberculosis was the probable cause of the destruction. This diagnosis was considered in our Case 1 but rejected. In our Case 2 the tuberculin test was negative.

Most cases of pyogenic spondylitis are characterized by an acute onset with localized pain and a high ESR (usually over 100 mm/h) and frequently increased anti-staphylolysin titre. Most cases have a tendency towards rapid recovery and there is a low incidence of relapse (AHLBACK *et al.* 1969). The two cases now published follow this pattern.

Bony changes can often be demonstrated only after 3 to 6 weeks. The micro-organism responsible for the disease could not be demonstrated in either case. However, the markedly increased anti-staphylolysin titre, which later became normal, strongly suggests a staphylococcus infection in our Case 1.

The atlanto-axial region is difficult to examine. Frontal and sagittal tomography was necessary in both our cases to demonstrate the extension of the destructive changes in the odontoid process as well as in the intervertebral joints. Pyogenic spondylitis in other parts of the spine is almost always localized within or close to the intervertebral disk. Relatively large intervertebral joints take the place of disks between the atlas and the axis. The arthritis in these joints probably occurs before the destruction of the odontoid process. This was evident in Case 1, in which the base of the process was seen to be destroyed before the whole process disappeared.

SUMMARY

Two cases of pyogenic atlanto-axial spondylitis with complete disappearance of the odontoid process are reported. The differential diagnosis in these rare cases is discussed.

ZUSAMMENFASSUNG

Es wird über zwei Fällen von pyogener Osteomyelitis des Atlas und Epistropheus berichtet, in denen der Zahnfortsatz des Epistropheus vollständig zerstört war. Die Differentialdiagnose dieser seltenen Fälle wird erörtert.

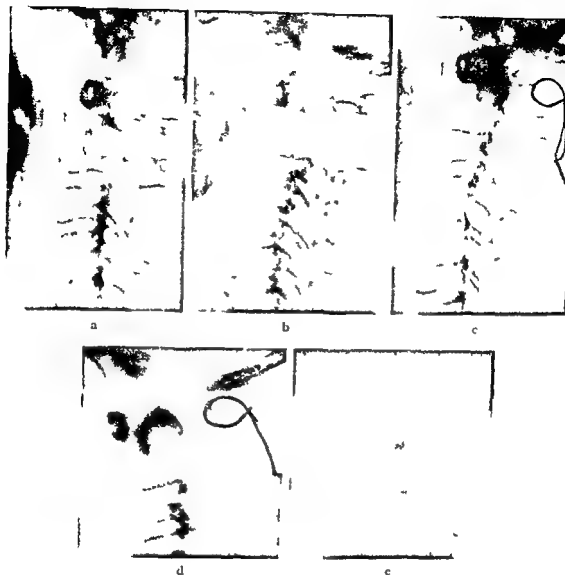


Fig. 2. Case 2. a) Two weeks after onset. Normal upper cervical region. b) Seven weeks after onset. The atlas is displaced anteriorly and caudally on the axis, diffuse swelling of retropharyngeal soft tissues. c) Three and a half months after onset. Regression of the soft tissue swelling (fusion performed). d) and e) Eight months after onset. All but the base of the odontoid process is absent, bony ankylosis of the left atlanto-axial joint and persistent atlanto-axial misalignment.

one and half years the apex of the process could again be demonstrated. FIELDING reported a case of a 17-month-old boy, who had marked retropharyngeal soft tissue swelling after trauma but otherwise normal radiographic appearances of the region. Seven years later the odontoid process with the exception of the apex was missing. These cases bear several similarities to our cases. They would appear

CORRECTION OF THE PELVIS IN BLADDER EXSTROPHY

A radiographic analysis

by

PAUL EDHOLM

The theoretical possibility of closing the diastasis of the pubic symphysis in bladder exstrophy by a modified form of osteotomy of the ilium has been investigated. It was believed that this operation might enable a better correction of the pelvis than is possible with the more conventional techniques. Roentgenograms from patients with this anomaly and from a group used as controls, obtained in a radiographic analysis of the orientation of the pelvic bones, were compared. The comparison was based on measurements of the angles between lines joining various skeletal reference points. This method of measurement has the advantage over the measurement of distances in that the determinations are independent of difference in size at different ages as well as in magnification between various radiographic projections.

Material This consisted of 27 cases of exstrophy of the bladder or epispadias, in which urograms, urethrocystograms and ordinary roentgenograms were available. The pelvic structures were clearly discernible in both frontal and lateral projections in sixteen of the cases, in twelve of which bladder exstrophy had been

Submitted for publication 4 November 1969

RÉSUMÉ

Presentation de deux cas de spondylite a pyogenes atlo axoïdienne avec disparition complete de l'apophyse odontoïde Discussion du diagnostic différentiel dans ces cas peu fréquents

REFERENCES

- AHLBACK S, COLLERT S and LINDBERG L. Non specific spondylitis. *Acta orthop scand* 40 (1969), 678
- FIELDING J W. Disappearance of the central portion of the odontoid process. A case report. *J Bone Jt Surg* 47 A (1965) 1228
- FRANK T J F. Osteomyelitis of the odontoid process of the axis (dens of epistropheus). *Med J Austr* 1 (1944) 198
- FREIBERGER R H, WILSON JR P D and NICHOLAS J A. Acquired absence of the odontoid process. A case report. *J Bone Jt Surg* 47 A (1965), 1231
- GWINN J L and SMITH J L. Acquired and congenital absence of the odontoid process. *Amer J Roentgenol* 88 (1962), 424
- KARLÉN A. Congenital hypoplasia of the odontoid process. *J Bone Jt Surg* 44 A (1962) 567
- LEACH R E, GOLDSTEIN H H and YOUNGER Donna. Osteomyelitis of the odontoid process. *J Bone Jt Surg* 49 A (1967), 369
- MARTEL W and BOLE G G. Pathologic fracture of the odontoid process in rheumatoid arthritis. *Radiology* 90 (1968) 948
- OELBERG JOHNSON G. A case of cervical spondylarthritis after tonsillectomy. *Acta orthop scand* 2 (1931) 302

pubis were taken as the centres of gravity and were also approximated. The nine lines are referred to in the text by their respective numbers.

The angle that each line formed with the normal to the base plane was measured in the frontal and lateral tracings. The direction of the line was marked out, with the aid of an instrument designed for the graphical calculation of angles between skeletal structures (LÖNNHOLM 1966), as a point in a diagram representing the surface of a hypothetical sphere of a radius large in relation to the size of the pelvis and with the femoral head at its centre (Fig. 3).

The diagram contained lines representing the meridians and parallels of the sphere, just as on a globe, and oriented so that the north pole represented the direction of the a.p. projection and the direction of the lateral projection was represented by the left terminal point of the 'equator' in the diagram. The diagram thus indicated the hypothetical sphere as viewed from a point located on the normal to the base plane, i.e. from approximately a cranial direction.

As the data in this investigation covered more than one hemisphere it was necessary to use a diagram representing a stereographic projection. The surface of the sphere was therefore projected on to a plane by rays coming from the point on the surface that lay farthest from the plane (Fig. 4), and with this projection a greater area than one hemisphere can be covered.

The directions of the nine lines were represented in the diagram by the points at which the lines produced intersected with the surface of the sphere (Fig. 5). All the lines except 5 and 6 were produced in a cranial direction. As lines 5 and 6 often coincided with the base plane, their directions could not be determined solely from the angles in the frontal and lateral projections wherefore it was necessary to construct a third projection of the line perpendicular to the base plane, i.e. the projection whereby the diagram became representative of the sphere (Fig. 6). The angle between the line and the direction of the frontal projection was found by computing its tangent as the ratio of the distances on the two films between the points defining the projection of the line on the base plane.

Each projection of a line is represented on the sphere by a great circle, two projections thus give two great circles whose points of intersection define the direction of the line. With three projections, as used in the case of lines 5 and 6, three great circles are obtained, which form on the sphere a small triangle whose centroid represents the direction of the line.

In two diagrams, one for each group, all the lines for each subject were entered as points, the exstrophy series is shown in Fig. 5.

Statistics. The various directions of lines for a group of subjects were represented by a group of points in the corresponding diagram, and the dispersion within the group was therefore due to inter subject variations in position during

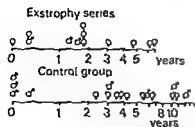
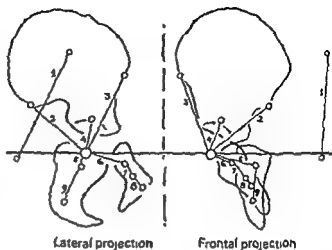


Fig 1 (above) Age and sex of the subjects comprising the bladder exstrophy series and the control group

Fig 2 (right) Tracings with the nine reference lines relating to a case of bladder exstrophy. The horizontal lines are the base lines



diagnosed, in none of them had osteotomy been carried out. They will be referred to below as the exstrophy series.

The comparison, or control, group comprised seventeen randomly chosen cases in which urography and urethrocytography had been performed. The composition of the two groups with respect to age and sex is presented in Fig 1.

Both urography and urethrocytography had usually been carried out in the exstrophy series as well, the urethrocytograms were however generally sufficient for the present purpose since as a rule several frontal and lateral films were available.

Method The following procedure was uniformly applied. Tracings were made of the frontal and lateral projections of the right half of the pelvis on a sheet of transparent paper. An approximate reconstruction of the ray path geometry was made from the two roentgenograms. A line was drawn on the two tracings to represent a base plane through the two beams passing through the lup-point in each of the two projections.

The following lines were then added to the tracings (Fig 2) between the centres of the first and fifth sacral vertebrae (1), between the centre of the femoral head and the posterior inferior iliac spine (2), the anterior superior iliac spine (3), the centre of the body of the ilium (4), the centre of the body of the ischium (5), the centre of the body of the pubis (6), between the centre of the body of the pubis towards the lateral margin of its superior ramus (7), a tangent to the medial part of the axis of the superior ramus of the pubis (8), from the centre of the body of the ischium to the first part of the ramus (9).

The centre of the femoral head and the long axis of the ischiatic and pubic ramus were approximated. The centres of the bodies of the ilium, ischium and

pubis were taken as the centres of gravity and were also approximated. The nine lines are referred to in the text by their respective numbers.

The angle that each line formed with the normal to the base plane was measured in the frontal and lateral tracings. The direction of the line was marked out, with the aid of an instrument designed for the graphical calculation of angles between skeletal structures (COHOLM 1966), as a point in a diagram representing the surface of a hypothetical sphere of a radius large in relation to the size of the pelvis and with the femoral head at its centre (Fig. 3).

The diagram contained lines representing the meridians and parallels of the sphere, just as on a globe, and oriented so that the north pole represented the direction of the a.p. projection and the direction of the lateral projection was represented by the left terminal point of the 'equator' in the diagram. The diagram thus indicated the hypothetical sphere as viewed from a point located on the normal to the base plane, i.e. from approximately a cranial direction.

As the data in this investigation covered more than one hemisphere it was necessary to use a diagram representing a stereographic projection. The surface of the sphere was therefore projected on to a plane by rays coming from the point on the surface that lay farthest from the plane (Fig. 4), and with this projection a greater area than one hemisphere can be covered.

The directions of the nine lines were represented in the diagram by the points at which the lines produced intersected with the surface of the sphere (Fig. 5). All the lines except 5 and 6 were produced in a cranial direction. As lines 5 and 6 often coincided with the base plane, their directions could not be determined solely from the angles in the frontal and lateral projections wherefore it was necessary to construct a third projection of the line perpendicular to the base plane, i.e. the projection whereby the diagram became representative of the sphere (Fig. 6). The angle between the line and the direction of the frontal projection was found by computing its tangent as the ratio of the distances on the two films between the points defining the projection of the line on the base plane.

Each projection of a line is represented on the sphere by a great circle, two projections thus give two great circles whose points of intersection define the direction of the line. With three projections, as used in the case of lines 5 and 6, three great circles are obtained, which form on the sphere a small triangle whose centroid represents the direction of the line.

In two diagrams, one for each group, all the lines for each subject were entered as points, the exstrophy series is shown in Fig. 5.

Statistics The various directions of lines for a group of subjects were represented by a group of points in the corresponding diagram, and the dispersion within the group was therefore due to inter subject variations in position during

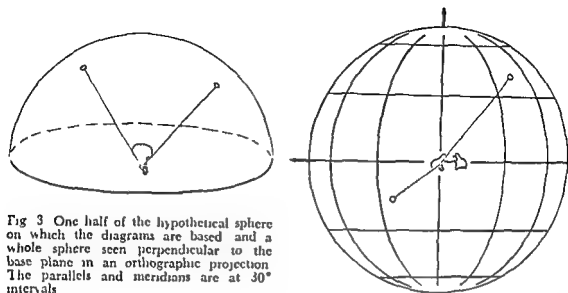


Fig 3 One half of the hypothetical sphere on which the diagrams are based and a whole sphere seen perpendicular to the base plane in an orthographic projection. The parallels and meridians are at 30° intervals.

the radiographic examinations and to biologic factors. The error of method should also be considered but this has been shown to be negligible compared to other sources of error (EDHOLM 1966).

Each of the nine lines had two distributions, one for the exstrophy series and the other for the controls. The mean direction of each distribution was calculated, as was the accuracy of this determination.

The geometric basis for a distribution of directions is the surface of a sphere. The range of the distribution usually occupies such a small part of the sphere that it can be approximated to a plane, and then the Gaussian distribution, which is based on a plane of infinite extent, can be used. In this study however the range of distribution was too great for this to be possible and therefore a theory developed by FISCHER, which is appropriate for measurements on a sphere, was applied.

Each member of distribution was regarded as a vector. A diagram was constructed on a transparent sheet so that, combined with the original diagram, it enabled the direction cosines in relation to the three axes of projection to be read off for each member. The resultant (R) of all the vectors in the distribution was then calculated. Its direction was the mean direction, and the accuracy of the determination was represented by a circle of confidence about this direction. If the probability that the true mean direction lies outside the circle of confidence is denoted by (P) and the cosine of the angle between the calculated mean direction and lines to the circle is (C) we have, according to FISCHER,

$$1 - C = \frac{N - R}{R} \left[\left(\frac{1}{P} \right)^{1/(N-1)} - 1 \right]$$

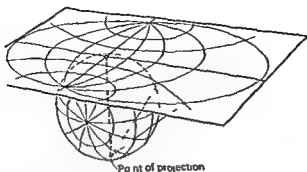


Fig 4 Stereographic projection of the surface of a sphere onto the base plane, the point of projection being indicated by an arrow

where (N) denotes the number of members composing the group. The true mean direction is the mean direction for the population the examination of which is limited to a sample. The circles of confidence at the 5 % level were calculated for all the directions in the two groups of subjects. The mean directions and circles of confidence were then entered in a new diagram (Fig 7). The two groups were examined and compared by means of the instrument.

Results

The differences between the exstrophy series and the control group were considered to be due largely to differences in rotation of the individual lines and of the three pelvic bones. An attempt was also made to represent the differences between the two groups as a single rotation of one half of the pelvis as a unit.

Ilium A comparison between the two groups was made as regards the mean directions of the three lines 4, 2 and 3, i.e. the lines from the femoral head to the body and the two spines of the ilium. The differences were ascribable to a rotation about an axis through the sacro-iliac articulation. In the exstrophy series the ilium was rotated outwards and upwards, with the result that the symphysis was widened. The axis of rotation lay in a ventrocraniolateral direction, as determined graphically with the instrument.

There was no appreciable difference in the shape of the ilium. The angle between lines 2 and 3 was 92° in the exstrophy series and 88° in the controls, a difference that is not significant.

Acetabulum The mean directions of the three lines 4, 5 and 6, from the femoral head to the centres of the ilium, ischium and pubis, respectively, formed

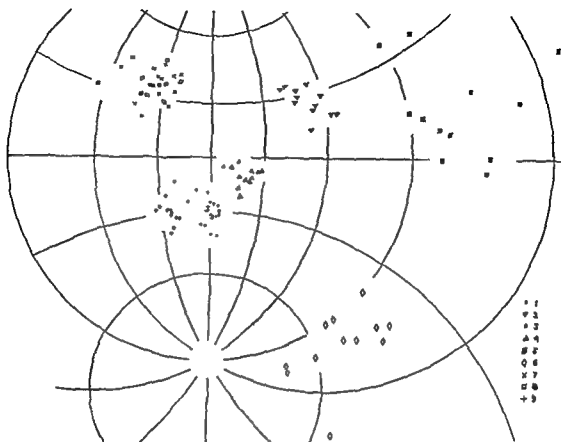


Fig 5 Stereographic projection of the directions of the nine lines for measurement in cases of exstrophy of the bladder. The parallels and meridians are at 30° intervals

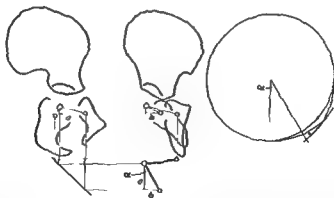


Fig 6 Method of calculating the directions of lines 5 and 6, using lateral (left) and frontal (middle) projections and constructing a stereographic diagram (right). The projection of the lines on the base plane is constructed below the frontal projection. The angle between the α projection is obtained from $\tan \alpha = b/a$. The sphere by three great circles, the parts of which are shown, the centroid of which denotes the direction of the line (small circle).

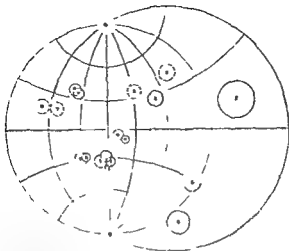


Fig 7 Circles of confidence at the 5 % level for the nine lines. The exstrophy series ■ represented by the full-drawn circles and the control group by the dashed circles

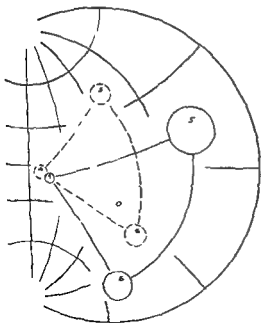


Fig 8 The orientation of the acetabulum in the exstrophy series (triangle formed by the broken lines) The small circles indicate the positions of the centroids.

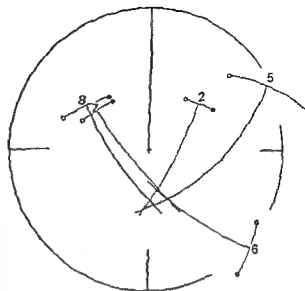


Fig 9 Construction of a common axis of correction for line 2 and for lines 5, 6, 7 and 8. The filled circles represent the exstrophy series and the open circles the control group. The shaded area indicates the probable direction of the axis.

a triad that represented the orientation of the fossa in relation to the head (Fig 8). In the diagram the angles between the lines formed a spherical triangle of about the same size in the two groups of subjects. The differences were not significant.

Angle between lines	4 and 5	5 and 6	4 and 6
Exstrophy series	84	67	76
Control group	73	76	75

The triangle was oriented differently in the two series and this was ascribable to a rotation about an axis having a cranioventral direction. The rotation was 15° for line 6, 42° for line 7, and 25° for line 8, values that were on an average greater than those recorded for the ilium. The rotation of the centroid of the triangle was 31° . The acetabulum faced in the caudolaterodorsal direction in the exstrophy series and caudolaterally in the controls. The larger value for the acetabulum triad may be accounted for by assuming that it first described a rotation identical with that of the ilium and then a further rotation about an axis through the femoral head.

Ischium and pubis The difference between the two groups in respect of the direction of lines 9 and 7, i.e. from the centres of the bodies of the ischium and pubis towards their respective rami, could be ascribed to a rotation about an axis with a cranioventral direction and of the same magnitude as the rotation of the ilium. A notable feature, however, was the additional rotation that the

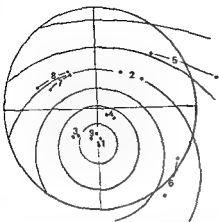


Fig 10

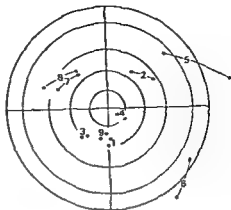


Fig 11

Fig 10 Tentative diagram with a correction axis (+) forming a ventral angle of 37.5° with the normal to the base. The parallel circles are centred on the axis, intervals of 20° . The filled circles represent the exstrophy series.

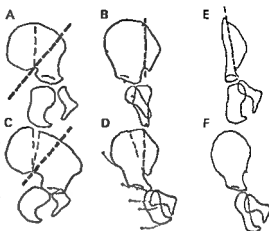
Fig 11 Same construction as in fig 10 but with the parallel circles centred on the normal to the plane.

centres of these bones described about an axis through the femoral head, this, however, was unaccompanied by any changes in the direction of the long axes. No obvious difference in the shape of the ischium was observed between the two groups, which was however the case with respect to the pubic bone. In the control group the superior ramus was well developed and curved medially, with a mean angle of 13° between lines 7 and 8, and formed a sharp junction at the symphysis with the inferior ramus. All these characteristics were less prominent in the exstrophy series. The superior ramus was less well developed and the mean angle between lines 7 and 8 was only 4° , the difference of 9° between the two groups is not significant ($10/30^\circ$ at the 5% level). The superior ramus continued in a shallow arc over into the inferior ramus.

The hemipelvis Because of the possibility of correction through osteotomy it was considered convenient to regard the difference between the two groups as being due to a single rotation of each half of the pelvis in the exstrophy series. In order to find the axis for this rotation the following construction was performed with the instrument for each line (Fig 9).

The two mean directions for the two groups were joined by an arc of a great circle, through the midpoint of which, and perpendicular to it, another arc of a great circle was drawn. A rotation that makes one mean direction coincide with

Fig 12 Lateral and frontal projections (A B) in a patient with bladder exstrophy aged 17 months. Rotation about a cranioventral correction axis is constructed graphically in (C) and (D). Rotation about a craniolateral axis is presented in (E). The frontal projection of the pelvis of a control subject aged 10 months is seen in (F).



the other has its centre on this new arc. Such arcs were drawn for all the lines except 1, 3, 4 and 9, the directions of which deviated only slightly from that of the correction axis. The arcs for the other lines intersected within a small region which indicated an axis having a cranioventral direction and making an angle of 30 to 45° with the normal to the base. A diagram containing all the mean directions was produced with a series of circles drawn about an axis at a ventral angle of 37.5° with the normal to the base (Fig 10), these circles denoted the direction of movement in a rotation about this axis. The difference between the two groups was found to be ascribable to a single rotation of the hemipelvis. By rotating the pelvis of the exstrophy patient back about this axis, an acceptable correction of all the lines should be obtainable. The differences between the groups in respect of lines 1, 3, 4 and 9 were so small that the circles of confidence intersected (Fig 7), and the direction of the correction was therefore not well defined, this would account for the deviations from the rest of the pattern displayed by lines 1 and 3.

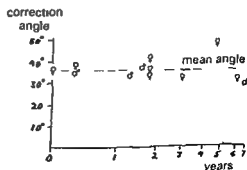


Fig 13 Correction angles for the subjects composing the exstrophy series; sex and age being indicated.

Discussion

In iliac-osteotomy by the methods in current use an attempt is made to correct the malposition by bilateral division of the ilium just lateral to the sacroiliac articulation and then by compression of the pelvis on each side of the osteotomy make the parts meet in the midline (SCHWARTZMAN & SCHULZ, O'PHELAN 1963). The osteotomy gap, which mostly forms a small lateral angle to the long axis of the body, is the axis for the corrective rotation.

A diagram of the case series, with circles about an axis coincident with the normal to the base plane, is presented in Fig. 11, this axis can be seen to be roughly parallel to the long axis of the body. The circles denote the paths of rotation about the axis and it will be noted that they do not entirely correspond with the changes in direction required to bring the exstrophy series into agreement with the control group.

A graphically constructed *a p* projection of a pelvis after osteotomy, in which the axis of correction has been given a small lateral angle, is shown in Fig. 12 E, this has been based on the pelvis in Fig. 12 A and 12 B. The geometric result leaves a good deal to be desired.

It is evident from the findings in this study that a cranioventral direction for the correction axis is desirable. If the correction were made so that that part of the pelvis which is lateral to the osteotomy could rotate about an axis having this direction and passing through the caudal tip of the osteotomy, the result as far as appearances are concerned would probably be more satisfactory than what could be obtained with a cranially directed axis. The validity of this supposition was tested by the following graphic construction. On *a p* and lateral films from a case of exstrophy a cranioventral axis was drawn across the caudal tip of a hypothetical osteotomy through the ilium. The axis was assumed to be perpendicular to a plane through the caudal tip of the osteotomy and through part of the pubis taken to represent the symphysis after the correction. The result of a rotation about this axis was constructed in lateral and frontal projections (Fig. 12 C and 12 D). After the correction, the pelvis in both projections appeared to be geometrically normal. The rotation will be the minimum achievable with this construction of the correction axis and the acetabulum will have the same orientation as in the control group. One disadvantage, however, is that there is no known technical means of effecting the rotation and then immobilizing the structure.

A calculation was made for all the twelve cases comprising the exstrophy series to determine the angle of rotation which with this correction would have produced closure of the symphysis. The results are presented in Fig. 13. The mean angle of correction was 36° . There was no appreciable age variation.

SUMMARY

A radiographic comparison has been made of the orientation of the pelvic bones in 12 cases of exstrophy of the bladder and a control group. The comparison was based on angles between lines joining various skeletal reference points, the calculations being performed graphically with a special instrument. Corrective rotation of the pelvic halves about a cranio-ventral axis in osteotomy for this deformity of the pelvis would apparently provide an acceptable geometric result.

ZUSAMMENFASSUNG

Ein radiographischer Vergleich der Orientierung der Beckenknochen bei 12 Fällen mit Exstrophie der Blase gegenüber der einer Kontroll-Gruppe wurde vorgenommen. Der Vergleich basiert auf den Winkeln der Linien, die verschiedene Referenzpunkte des Skeletts verbinden, und die Berechnungen wurden graphisch mit einem besonderen Instrument durchgeführt. Eine korrigierende Rotation der Beckenhälften um eine cranio-ventrale Achse bei einer Osteotomie wegen dieser Deformation des Beckens würde wahrscheinlich zu einem annehmbaren geometrischen Resultat führen.

RÉSUMÉ

L'auteur a fait une comparaison radiographique de l'orientation des os dans 12 cas d'exstrophie vésicale et dans un groupe de sujets témoins. La comparaison a été basée sur les angles formés par des lignes joignant différents points osseux de référence; les calculs ont été faits graphiquement au moyen d'un instrument spécial. Une rotation corrective des moitiés du bassin autour d'une axe oblique en haut et en avant donnerait apparemment un résultat géométrique acceptable dans l'ostéotomie pour le traitement de cette malformation du bassin.

REFERENCES

- EDHOLM P. Anatomic angles determined from two radiographic projections. *Acta radiol* (1966) Suppl. No. 259.
- FISCHER R. F. Dispersion on a sphere. *Proc. roy. Soc. A* 217 (1953) 295.
- MUECKE E. C. and CURRARINO G. J. Congenital widening of the symphysis. *Amer. J. Roentgenol* 103 (1963), 179.
- SCHULTZ W. G. Plastic repair of exstrophy of bladder combined with bilateral osteotomy of ilia. *J. Urol* 79 (1958) 453.
- An ideal surgical correction of ectopia vesicae. *J. int. Coll. Surg.* 31 (1959) 674.
- SCHWARTZMAN J. H. Cited by Schultz.
- TRENDELENBURG F. The treatment of ectopia vesicae. *Amer. Surg.* 44 (1906) 281.
- WEISS G., BECKER A. J., BERDON W. E. and BAKER D. H. Epispadias. *Radiology* 90 (1968) 85.

SEMI-AUTOMATIC CONSTRUCTION AND COMPUTER ANALYSIS OF VOLUME CURVES AND PRESSURE- VOLUME CURVES IN LEFT VENTRICULAR CINEANGIOGRAPHY

by

LARS BJÖRK

Different methods have been described for calculating the volumes of the cardiac chambers, especially the left ventricle, with the aid of angiocardiology. The construction of volume curves from the left ventricle by full size angiocardiology with an exposure frequency of 6 per second has also been attempted by using data from several cardiac cycles (DODGE et coll 1956, 1966 and ARVIDSSON 1958, 1961, inter alios). Cineangiocardiology with exposure frequencies of 100 per second or more are however more suitable for building such curves (RUSHMER & THAL 1951, CHAPMAN et coll 1958, 1966 GRIFFE et coll 1959 BRUN et coll 1966, inter alios).

The routine use of left ventricular volume curves produced with the aid of angiocardiology and pressure volume curves, and their further analysis, should mean considerable diagnostic and probably also prognostic gains in the assessment of patients with cardiac disease (DODGE et coll, BRUN et coll inter alios). Increased information on the state of the myocardium, better

Submitted for publication 5 September 1969

evaluation of the relative importance of so-called valvular and myocardial factors, and a more reliable assessment of the effect of surgical and other therapeutic measures should thus be obtained

In spite of these possibilities, however, such curves and their further analysis have as yet been put to no practical use in cardiology. The reason for this is the large amount of information that needs to be analysed to produce results. The task of manually constructing and analysing the curves is time-consuming. The manual construction of a volume curve for the left ventricle during one cardiac cycle (40 exposures/second) appears to require a working time of about 8 hours. Methods for automatic or semi-automatic construction of pressure-volume curves are desirable and the need of computer aid for their analysis is clear.

The technique for semi automatic construction of pressure curves, pressure-volume curves and the computerized subsequent analysis of these curves will be described.

Material and Methods The material consisted of the cineangiocardigrams obtained from the left ventricle by catheterization and angiocardiology, and simultaneous pressure recordings from the left ventricle, aorta, and sometimes one other heart chamber. The pressure recordings were made either via teflon catheters introduced transeptally into the left atrium or left ventricle, or via grey Ödman catheters passed percutaneously into the left ventricle. The pressure in the ascending aorta was recorded as a rule via polythene catheters (PE 160) inserted percutaneously, these were connected to pressure transducers (Elema-Schonander) and the pressures recorded on a Mingograph, type 81 (Elema-Schonander). The ECG was recorded by the conventional method simultaneously with the pressure recording. The paper speed was 100 mm/second.

Contrast medium (usually Isopaque 350) for the angiocardiographies in a dose of about 0.5 ml/kg body weight was injected into the left atrium via transseptal catheters or into the left ventricle via catheters inserted in a retrograde direction. The injection was given with a Gidlund syringe, with the pressure kept low (3.5 kg/cm²) so as to prevent as far as possible any movement of the catheter and thereby the induction of extra systoles during the injection. The roentgen tube was a Siemens rapidly rotating high load tube with a nominal focus dimension of 0.6 mm × 0.6 mm.

Cinerecording in one plane was performed by means of a 9" image intensifier and a 35 mm film camera (Arriflex) at an exposure rate of 40 per second. The exposure data were 50 to 70 kV and 325 mA, duration of each cinepulse 0.003 seconds. A geometric magnification factor of 1.3 to 1.8 was employed.

Gevaert's Scopix G, high definition film was developed for 11 minutes in fine-grain developer. A special synchronization arrangement (Björk 1961), which gives markings both on the cinefilm and via one of the channels on the Mingo-graph paper, made possible exact synchronization between each frame on the cinefilm and the corresponding segments of the simultaneously recorded pressure curves and ECG.

The patient was placed in the supine position for the angiographic examination with the right side rotated upwards towards the image intensifier so that the longitudinal axis and greatest projection of the left ventricle lay as near as possible on one plane perpendicular to and in the centre of the beam pathway in the image recording system. Before or after the angiocardiology a ruler with millimeter markings was placed in the same position and on the same level as the left ventricle. A short cinerecording was made of the ruler, and in this way a reference was obtained on the same film strip as the angiocardigram for the magnification in the image recording system and in the following projection system.

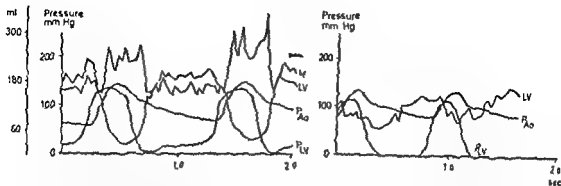
The cinefilms obtained from the left ventricular angiographies were placed in a special plotting projector and projected frame by frame, highly magnified, on a transparent screen, built into the latter was a recording coordinate system. The contour of the left ventricle was followed manually, and the coordinates required for calculating the volume of the left ventricle were thereby established. These coordinates were fed automatically into a writer that punched a tape from which the coordinate values were then supplied to a computer. The calibrated pressure curves were obtained from a so called curve reader and the values were fed similarly via punched tape to the computer. Recordings from at least two consecutive cardiac cycles with a normal heart rhythm were aimed at, and in most cases obtained.

The following mathematical formula was used for the calculation of the left ventricular volume with one cineangiographic projection.

$$V = \frac{LD^3}{2}$$

where $D = 4A/L$, V = the volume of the left ventricle, L = the longest diameter of the projected area and A = the projected area. This formula was studied in autopsy material by DAVILA & SANMARCO (1966) who reported good correlation between the true and the roentgenologically measured volumes of the left ventricle by the method.

The muscle mass of the left ventricle was assumed to be equally distributed around the lumen of the ventricle, as depicted in the cineangiocardigrams. The thickness of the muscle wall was measured at the anterolateral wall of the left



Figs 1 and 2 Volume and pressure curves in a patient with moderate aortic insufficiency (left) and in a patient with diffuse myocardial affection (right) V_L — left ventricular muscular volume, V_V — left ventricular volume, P_{Ao} — aortic pressure, P_{LV} — left ventricular pressure

ventricle, where the coordinates for this thickness, at least in diastole, may be determined with considerable reliability. For calculation of the volume of the muscle mass of the left ventricle, the left ventricular volume was then subtracted from the volume of a large rotation body comprising both the musculature and lumen of the left ventricle and calculated according to the above formula. The muscle volume obtained was then inserted in the same diagram as the volume of the left ventricle.

For further analysis, the computer was programmed to calculate the first derivative of the left ventricular pressure curve and the first derivative of the left ventricular volume curves. These are presented, like the other data, in the form of automatically drawn diagrams. The pressure-volume curve for the left ventricle was also drawn automatically. This gave the work performed by the left ventricle as well as a graphic presentation of the pressure and volume levels at which this work was achieved. The product of the aortic pressure and the first derivative for the volume of the left ventricle was also calculated, this was expressed as a function of time and constitutes a measure of the 'static' work of the heart. The pressure difference between the left ventricle and aorta was also calculated. The product of this difference and the first derivative of the volume curve was expressed similarly as a function of time and corresponds to the 'dynamic' work of the heart.

Preliminary results

The clinical value of this method cannot be assessed since the technique described above has been used only in about 30 cases. The following may be regarded as examples of its possibilities.

Curves obtained for a patient with dominating aortic insufficiency of moderate degree are presented in Fig 1. The curves represent, from above

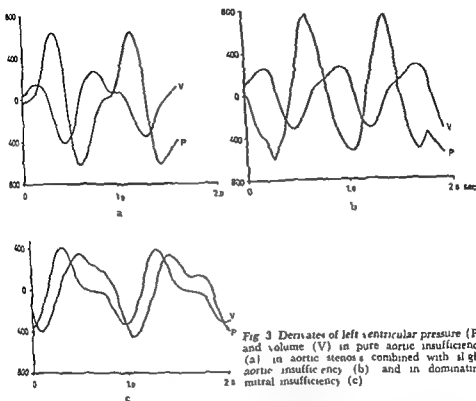


Fig 3 Derivates of left ventricular pressure (P) and volume (V) in pure aortic insufficiency (a) in aortic stenosis combined with slight aortic insufficiency (b) and in dominating mitral insufficiency (c)

downwards, the left ventricular muscle volume, the left ventricular volume, the aortic pressure and the left ventricular pressure. The curve for the muscle volume of the left ventricle varies widely, especially during ventricular systole, while it exhibits a more even and constant course during diastole. This probably reflects the fact that it is only in diastole that the technique used for measurement of the left ventricular muscle volume gives a fairly good correlation to the true volume. The difficulties in measuring the thickness of the ventricular wall in systole are greater, and the assumptions regarding the distribution of the muscle mass are also probably no longer valid, nor therefore the mathematical formula used. The value of the attempts to calculate the muscle volume of the left ventricle is thus uncertain. It would be desirable to attempt a correlation between the measured volume and the true volume obtained in an autopsy material. It is possible that the muscle volume of the left ventricle in diastole may be fairly well correlated to the true volume, however, and the value obtained in diastole might possibly be usable for further calculations.

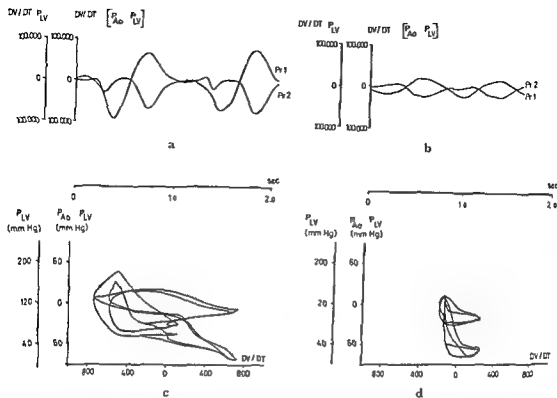


Fig 4 The product of the derivatives of left ventricular volume and aortic pressure (Pr 1) and the product of the same derivative and the pressure difference between left ventricle and aorta (Pr 2) a) Moderate aortic insufficiency b) Diffuse myocardial affection c) Integrals of the curves in (a) d) Integrals of the curves in (b)

The volume curve for the left ventricle exhibits a number of variations in diastole. Several of these variations are certainly due to artefacts and are subject to interpretation errors, a matter discussed in more detail below. The systolic and diastolic volume and the stroke volume for the left ventricle may be obtained directly from the left ventricular curve. These values may of course also be recorded directly in numerical form, if desired. The stroke volumes could be compared with stroke volume values obtained by the Fick method immediately before the angiocardigraphies in five cases with good agreement between the values obtained by the two methods. Fig 2 illustrates the left ventricular volume curve and pressure curves for the aorta and left ventricle in a patient with a diffuse myocardial lesion. Small and partly irregular volume variations in the left ventricle between systole and diastole are apparent.

In Fig 3, examples are presented of the derivatives of pressure and volume in patients with different valvular disorders (P = pressure derivative and V = volume derivative). The pressure and volume derivatives are illustrated for a

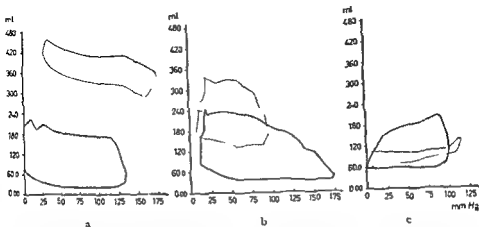


Fig 5 Pressure-volume loops for the left ventricle a) Well compensated aortic insufficiency (solid line) and aortic insufficiency and heart failure (dotted line) b) Moderate aortic insufficiency in two patients c) Dominating mitral insufficiency (solid line) and diffuse myocardial affection (dotted line)

patient with dominating aortic stenosis combined with mild aortic insufficiency in Fig 3a and the derivatives for a patient with dominating mitral insufficiency in Fig 3c. The derivatives represent essential differences in the different patients, and it is thus possible that analysis of the derivatives could give detailed and exact information on the contraction pattern of the left ventricle in various cardiac diseases. Assessment of the value of these derivatives must be deferred, however, until more experience has been gained and knowledge of their appearances in normally functioning left ventricles obtained.

Both the product of the volume derivative and the aortic pressure, as well as the product of the volume derivative and the pressure difference between the left ventricle and aorta, are included in Fig 4. The former product comprises a measure of the 'static' work of the heart, and the latter a measure of its 'dynamic' work. The appearances of these curves differ essentially. The left ventricle of the patient in Fig 4a may be considered to have a good function, despite the presence of moderate aortic insufficiency, while in the patient in Fig 4b, with the diffuse myocardial lesion, the function of the left ventricle and thereby the work it performs are considerably reduced. This is even more clearly evident in Fig 4, c and d, in which the integrals of corresponding curves for the two patients are shown.

The pressure-volume curves for the left ventricle express clearly the left ventricular function. The area enclosed by the pressure volume curve represents the work of the left ventricle, and from the position of the curve in the diagram

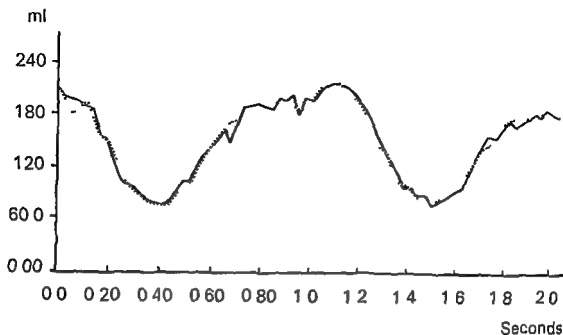


Fig 11 Good agreement between two left ventricular volume curves obtained from double reading of the same cineangiogram with 3 week intervals

the pressure and volume levels at which this work is performed may be observed and determined directly

One of the pressure volume curves in Fig 5a was obtained for a well compensated patient with aortic insufficiency (the same patient as in Fig 1). The left ventricle of this patient had a relatively large work output, at a normal pressure level but a somewhat elevated volume level. The other patient (dashed curve) also had aortic insufficiency but was on the verge of cardiac failure, his left ventricle was performing less work and furthermore this lower work output was produced at a very high volume level and at a moderately raised pressure level. Similar examples of pressure volume curves in two patients with aortic insufficiency are given in Fig 5b. The solid curve indicates moderate aortic insufficiency. The left ventricle had a fairly high work output at a somewhat elevated pressure level and at a slightly raised volume level. The other patient (dashed curve) also had aortic insufficiency but the left ventricle was performing less work at, especially, a greatly raised volume level. The solid curve in Fig 5c represents the left ventricular work in a patient with dominating mitral insufficiency. The ventricle probably had a normal work output, achieved at a slightly elevated volume but at a normal pressure level. The dashed curve represents the work of the left ventricle in a patient with myocardial insufficiency based on coronary arteriosclerosis. The left ventricle was apparently performing

little work at a high systolic volume level but a normal diastolic level and at a normal diastolic pressure

Discussion

It is important in a study of this kind that the many sources of error that can arise in the collection of primary data and in the subsequent analysis should be considered and eliminated as far as possible. Exact pressure recordings are obviously necessary. A continuous check as well as careful calibration and supervision of the pressure recording system are therefore essential. The paper speed in the Mingograph may possibly vary, investigation into the Mingograph we used disclosed variations not exceeding 1%. With the synchronization system used, which gives markings simultaneously on the Mingograph paper and the cinefilm, minor variations in the paper rate in the Mingograph, and even variations of the exposure frequency in the film camera, are however of little importance in the final evaluation of the data. They are of some significance, however, for the appearances of the pressure curves, and to some extent for the visual assessment of the course via the cinefilm.

It is also of importance to the image intensifier and film camera, correctly in relation to one another, of the image. A simple way of checking that the image recording system is functioning satisfactorily is by recording with this system the image of a fine-mesh square wire network. Variations in the ideal recording conditions in different parts of the image field are easily detected by this technique.

An important source of error in this connection is the distortion produced by the image intensifier. This arises partly from a non parallel roentgen beam and partly from the fact that the primary screen of the image intensifier is not plane but slightly convex. As a result, the so-called pincushion effect is produced, i.e. a square is not reproduced as a square but as a cushion like figure with the sides of the square bulging slightly inwards. In addition to this general distortion in the image intensifier, which results in an error in image recording increasing symmetrically from the centre towards the periphery, irregular distortions often also occur in the image intensifier, even in the centre of the image field. Careful adjustment of the electron-optical system of the image intensifier can reduce these aberrations to a minimum and to such an order of magnitude that they have no practical importance for the measurements in question. Irregularity of form of the image due to pincushion distortion cannot be compensated in a simple way. Recording of the image of a wire network with square meshes of known dimensions, and correction of every coordinate

on the image by this means would be a conceivable but time consuming and complicated procedure. Measurements on the image intensifier used here have indicated that the distortion in the periphery amounts to about 10 %.

The entire field of the image intensifier was never utilized in the present investigations, however. Only the central part, with a diameter of about 12 cm, was usually used, the maximal deviations of this central image field from the ideal image amount to less than 1 %. The error amounts to 4 % about 2 cm outside this central image field and then increases rapidly to 10 % at the periphery. This means in practice that this error in image recording may be ignored for normal-sized and moderately enlarged left ventricles. Only for the very large end-diastolic volumes of the left ventricle does this error in image recording bear any importance, it may then give excessively large diastolic volumes and consequently too high values for the stroke volume as well.

The decreasing resolving power of the image intensifier from the centre and out towards the periphery meant no problem in this study. The resolving power in the part of the image field utilized was high enough on all occasions to allow good delimitation of the contrast-filled left ventricle from its surroundings. The exposure rate used in the film camera was 40 per second, which was the highest rate with the present equipment. Theoretically it may be accepted that an exposure frequency of 25 per second should be a sufficiently high sampling rate to capture most of the courses in the activity of the heart, the exposure rate of 40 per second should thus give satisfactory demonstration of most of them. It is clear, however, that certain events in the heart, especially at the beginning and end of systole and diastole, have a frequency of up to 100 to 200 periods/second. Thus, in order to study these courses in detail, high exposure frequencies are desirable. This means, among other things, that the use of a TV system in place of cinefilm would be impossible, since TV systems have a maximal exposure rate of 50/second (or 60/second). The value of studying such rapid courses must, however, be weighed against the greatly increased number of data obtained for analysis at high exposure frequencies compared with those at moderate frequencies, such as the 40/second used here. Factors such as installation costs, costs per examination and roentgen dose to the patient per examination must also be considered.

The contrast injection with a volume of about 15 to 20 ml/second into the left atrium or left ventricle may conceivably influence the volumes of the cardiac chambers and even the function of the heart. SANMARCO *et coll.* (1966) working with dogs reported an increased end-diastolic volume and a raised stroke volume during the first three beats in association with the injection of contrast medium into the left ventricle. By avoiding if possible the use of the first three beats after the injection for measurements, and by as far as possible

making the injection into the left atrium instead of the left ventricle, this effect may be largely avoided. The more marked changes in the haemodynamics that appear after the injection of contrast medium, in the form of increased cardiac output and rate, and decreased blood pressure, occur later in the course and need not, as a rule, influence measurements of the left ventricular volume on injection into the left atrium or left ventricle. This effect may on the other hand influence the measurements if the injection is given intravenously or into the right side of the heart.

One prerequisite for satisfactory functioning of the formula used for calculation of the left ventricular volume is that the longitudinal axis and largest projection of the ventricle are recorded in a plane perpendicular to the central beam in the image recording system. Experience has established that with the guidance of the catheters, the position of the patient can be adjusted so that the greatest projection of the left ventricle lies in or near to the horizontal plane when he is recumbent. Minor deviations from the ideal position are, of course, unavoidable. The importance of such deviations has been studied with the aid of plasticine models of left ventricles of various sizes. These studies disclosed that deviations of up to 10° from the ideal position in the plane were of no importance for the size either of the projected area or of the longitudinal axis. Deviations of 15° gave an area and longitudinal axis about $\frac{1}{2}\%$ smaller than the true dimensions, and deviations of 20° produced differences of up to 8% in these measurements. Recording in two planes has indicated that no deviations of more than 10° from the ideal position of the left ventricle occur. The variations in the position of the left ventricle that occur during the cardiac cycle are small and not of such an order of magnitude as to influence the measurements in question.

It is important in the calculation of the magnification that the ruler with millimeter markings is placed in the same position and on the same plane as the left ventricle. This can be done with a deviation of about 1 cm with the guidance of the position of catheters and other landmarks. This means that an error of $\pm 3\%$ in the calculated volumes can occur. To reduce this error it is necessary for the position of the ruler to be set even more carefully with the aid of fluoroscopy with a horizontal beam.

As mentioned previously the mathematical formula used for calculating the left ventricular volume, based on a projection of the left ventricle, has proved to be well correlated to the true volume (DAVILA & SANMARCO 1966). These authors stated that the correlations between the true and calculated volumes were practically as good with this procedure as with the two-plane system. The advantage of employing only one plane is again the smaller number of data that need to be analysed in comparison with the two-plane procedure. One

on the image by this means would be a conceivable but time-consuming and complicated procedure. Measurements on the image intensifier used here have indicated that the distortion in the periphery amounts to about 10 %.

The entire field of the image intensifier was never utilized in the present investigations, however. Only the central part, with a diameter of about 12 cm, was usually used, the maximal deviations of this central image field from the ideal image amount to less than 1 %. The error amounts to 4 % about 2 cm outside this central image field and then increases rapidly to 10 % at the periphery. This means in practice that this error in image recording may be ignored for normal-sized and moderately enlarged left ventricles. Only for the very large end diastolic volumes of the left ventricle does this error in image recording bear any importance, it may then give excessively large diastolic volumes and consequently too high values for the stroke volume as well.

The decreasing resolving power of the image intensifier from the centre and out towards the periphery meant no problem in this study. The resolving power in the part of the image field utilized was high enough on all occasions to allow good delimitation of the contrast-filled left ventricle from its surroundings. The exposure rate used in the film camera was 40 per second, which was the highest rate with the present equipment. Theoretically it may be accepted that an exposure frequency of 25 per second should be a sufficiently high sampling rate to capture most of the courses in the activity of the heart, the exposure rate of 40 per second should thus give satisfactory demonstration of most of them. It is clear, however, that certain events in the heart, especially at the beginning and end of systole and diastole, have a frequency of up to 100 to 200 periods/second. Thus, in order to study these courses in detail, high exposure frequencies are desirable. This means, among other things, that the use of a TV system in place of cinefilm would be impossible, since TV systems have a maximal exposure rate of 50/second (or 60/second). The value of studying such rapid courses must, however, be weighed against the greatly increased number of data obtained for analysis at high exposure frequencies compared with those at moderate frequencies, such as the 40/second used here. Factors such as installation costs, costs per examination and roentgen dose to the patient per examination must also be considered.

The contrast injection with a volume of about 15 to 20 ml/second into the left atrium or left ventricle may conceivably influence the volumes of the cardiac chambers and even the function of the heart. SANMARCO *et coll* (1966) working with dogs reported an increased end diastolic volume and a raised stroke volume during the first three beats in association with the injection of contrast medium into the left ventricle. By avoiding if possible the use of the first three beats after the injection for measurements, and by as far as possible

making the injection into the left atrium instead of the left ventricle, this effect may be largely avoided. The more marked changes in the haemodynamics that appear after the injection of contrast medium, in the form of increased cardiac output and rate, and decreased blood pressure, occur later in the course and need not, as a rule, influence measurements of the left ventricular volume on injection into the left atrium or left ventricle. This effect may on the other hand influence the measurements if the injection is given intravenously or into the right side of the heart.

One prerequisite for satisfactory functioning of the formula used for calculation of the left ventricular volume is that the longitudinal axis and largest projection of the ventricle are recorded in a plane perpendicular to the central beam in the image recording system. Experience has established that with the guidance of the catheters, the position of the patient can be adjusted so that the greatest projection of the left ventricle lies in or near to the horizontal plane when he is recumbent. Minor deviations from the ideal position are, of course, unavoidable. The importance of such deviations has been studied with the aid of plasticine models of left ventricles of various sizes. These studies disclosed that deviations of up to 10° from the ideal position in the plane were of no importance for the size either of the projected area or of the longitudinal axis. Deviations of 15° gave an area and longitudinal axis about 4% smaller than the true dimensions, and deviations of 20° produced differences of up to 8% in these measurements. Recording in two planes has indicated that no deviations of more than 10° from the ideal position of the left ventricle occur. The variations in the position of the left ventricle that occur during the cardiac cycle are small and not of such an order of magnitude as to influence the measurements in question.

It is important in the calculation of the magnification that the ruler with millimeter markings is placed in the same position and on the same plane as the left ventricle. This can be done with a deviation of about 1 cm with the guidance of the position of catheters and other landmarks. This means that an error of $\pm 3\%$ in the calculated volumes can occur. To reduce this error it is necessary for the position of the ruler to be set even more carefully with the aid of fluoroscopy with a horizontal beam.

As mentioned previously the mathematical formula used for calculating the left ventricular volume, based on a projection of the left ventricle, has proved to be well correlated to the true volume (DAVILA & SANMARCO 1966). These authors stated that the correlations between the true and calculated volumes were practically as good with this procedure as with the two-plane system. The advantage of employing only one plane is again the smaller number of data that need to be analysed in comparison with the two-plane procedure. One

special difficulty arises when the contractions of the left ventricle are no longer symmetric, as they usually are. This occurs, for example, in residual conditions after myocardial infarction. If a high-degree deformation of the lumen and contraction pattern of the ventricle has occurred, the mathematical formula is, of course, no longer completely valid. But the fact that in the described mathematical formula the area worked, which in itself involves an integration, the source of error is also smaller than if only diameters were worked. Similarly, several injections of contrast medium may make it possible to arrive at that projection of the left ventricle which completely encompasses the immobile or abnormally contracting part of its wall. This means that the appearances of the ventricle have again been brought closer to those of the imaginary mathematical model.

An important source of error lies in the establishment of the coordinates for the left ventricular volume, i.e. in the reliability and constancy with which the contour of the left ventricle can be followed when it is projected in the recording coordinate system. A good result necessitates that the cinefilm obtained should be of high quality, with as high definition as possible and with relatively high contrast, all this facilitates the delimitation of the contrast-filled left ventricle. A further requirement is an experienced observer with a good knowledge of anatomy who can make the necessary anatomical demarcations. The reliability of the results was studied by double determinations made by two observers simultaneously at an interval of three weeks. The constancy in delimitations of the contour of the left ventricle, and thereby in the establishment of the coordinates, was found to be satisfactory, and the volume curves for the left ventricle presented good agreement from the two different determinations (Fig. 6). Differences in the volume curves from the two determinations occurred especially in diastole. These on analysis proved to be due to some inconstancy in the demarcation of the left ventricle from the likewise contrast-filled aorta.

It should be pointed out that the procedure described for the construction of volume curves and pressure-volume curves, and subsequent computer analysis of these curves, is based entirely on primary material which is being collected at present in connection with investigations of cardiac patients. The patients will not therefore be troubled by further diagnostic measures, and no further claims need to be made on hospital resources. The technique used means a new way of analysing and presenting information which otherwise is 'concealed' among the large number of data collected at cineangiocardiology with simultaneous pressure recordings. The extra apparatus required consists of an arrangement for synchronization of roentgen cinefilms and pressure recordings. (The cost of such an arrangement would amount to about 2 000 Swed. Kr.)

The costs of plotting the cineangiocardigrams from the left ventricle and

the subsequent computer analysis have been estimated to be about 200 Swed Kr per patient in a current test series of 30 patients. With routine use of this procedure this cost could probably be reduced considerably and the total cost of an analysis of this kind would perhaps lie between 100 and 150 Swed Kr. The total cost of the investigation of a cardiac patient in a special clinic with heart catheterization and angiocardiology is not known but may be estimated to between 2 000 and 3 000 Swed Kr. In the light of such costs, the extra expenditure for the computer analysis must be regarded as relatively small.

A considerable portion of the costs for the analyses are connected with the actual plotting work, which at present is performed manually and which, although it can be done fairly quickly in the special plotter, still requires about 30 to 60 minutes per patient. This staff demanding and time consuming part of the work may be reduced by using apparatus that allows fully automatic determination of the volume variations of the left ventricle from cinefilms.

Preliminary trials have been carried out with a Quantumet Image Analysing Computer (QTM) (Metals Research Ltd, Melbourne, England), which was originally constructed for measurement and counting of particles of different kinds (Björk & Eriksson 1969). QTM works with a television scanning system in which areas and figures with certain density levels can be recognized in projected images and their sizes and diameters calculated. This apparatus after an adjustment for each cinefilm enables true variations in the left ventricular area as well as variations of the longitudinal axis to be determined automatically frame for frame. QTM for this purpose must be complemented by an automatic feed for the film and an automatic recording arrangement, e.g. a tape punch.

Acknowledgement

The method of construction of volume curves and pressure volume curves and for their further analysis was developed in collaboration with Saab Linköping Sweden, (Engineer Carl Joelsson). This work was supported by a grant from the Swedish National Association against Heart and Chest diseases.

SUMMARY

A technique for the semi automatic construction of volume curves and pressure volume loops from data collected at left ventricular cineangiocardiology, and computerized analysis of these curves have been used in a series of 30 cases. Examples of the possibilities of obtaining increased information on the function of the left ventricle with the method are presented.

ZUSAMMENFASSUNG

In einer Serie von 30 Fällen wurden halbautomatische Volumen und Druckvolumenkurven während der Cineangiographie des linken Ventrikels angelegt und mittels einer Datenverarbeitungsmaschine analysiert. An Beispielen werden die Möglichkeiten, mehr Information über die Funktion des linken Ventrikels zu erhalten, illustriert.

RÉSUMÉ

L'auteur a utilisé dans 30 cas une technique semi automatique de construction de courbes de volume et de diagramme de pression volume à partir des données recueillies par cine angiographie du ventricule gauche, et a fait analyser ces courbes par ordinateur. Il donne des exemples dans lesquels cette méthode a permis d'obtenir plus d'informations sur la fonction du ventricule gauche.

REFERENCES

- ARVIDSSON H. Angiocardiographic observations in mitral disease, with special reference to volume variations in the left atrium. *Acta radiol* (1958) Suppl. No. 158.
- Angiocardiographic determination of left ventricular volume. *Acta radiol* 56 (1961) 321.
- BJÖRK L. Velopharyngeal function in connected speech. *Acta radiol* (1961) Suppl. No. 202.
- and ERIKSSON U. Automatic measuring of areas of varying size. To be published.
- BRUN PH., GESCHWIND H., KILINNIK L. et coll. Courbes de volume ventriculaire gauche par cinéangiographie biplane à 100 images par seconde. *Cœur et Médecine interne* 5 (1966), 415.
- CHAPMAN C. B., BAKER O., MITCHELL J. H. and COLLIER R. G. Experiences with a cine fluorographic method for measuring ventricular volume. *Amer J Card* 18 (1966) 25.
- — REYNOLDS J. and BONTE F. J. Use of biplane cinefluorography for measurement of ventricular volume. *Circulation* 18 (1958), 1105.
- DAVILA J. C. and SANMARCO M. E. An analysis of the fit of mathematical models applicable to the measurement of left ventricular volume. *Amer J Card* 18 (1966) 31.
- DODGE H. T. and TANNENBAUM H. L. Left ventricular volume in normal man and alterations with disease. *Circulation* 14 (1956), 927.
- SANDLER H., BANLEY W. A. and HAWLEY R. R. Usefulness and limitations of radiographic methods for determining left ventricular volume. *Amer J Card* 18 (1966) 10.
- GRIBBE P., HIRVONEN L., LIND J. and WEGELIUS C. Cineangiocardigraphic recordings of the cyclic changes in volume of the ventricle. *Cardiologia* 34 (1959) 348.
- RUSIMER R. F. and THAL N. Mechanics of ventricular contraction. cinefluorographic study. *Circulation* 4 (1951), 219.
- SANMARCO M. E., FRONEK K., PHILIPS C. M. and DAVILA J. C. Continuous measurement of left ventricular volume in the dog. II. Comparison of washout and radiographic techniques with the external dimension method. *Amer J Card* 18 (1966) 584.

PHLEBOGRAPHIC CHANGES IN ARTERIOMEGALY

by

M LEA THOMAS and M R ANDRESS

LERICHE in 1943 described in detail a patient with elongation and dilatation of the right common iliac artery simulating an aneurysm. At operation, in addition to the dilated and elongated common and external iliac arteries, he found a similarly though less markedly lengthened and dilated common iliac vein which he considered to be of twice normal calibre, there was also dilatation of the origin of the inferior vena cava. This author had first drawn attention to the arterial condition a year earlier (LERICHE 1942) and since that time there have been a very large number of descriptions of lengthening, dilatation and tortuosity of arteries at many sites in the body (LERICHE 1947, 1954, LEGER & CERBONNET 1950, HULTEN GYLLENSTEN *et coll* 1959, BARIETY *et coll* 1961, CASTEN & FORMAN 1962, WAREMBOURG *et coll* 1963, ACKERMAN & BUTCHER 1964, STAPLE *et coll* 1966, ERTLGRUL 1967, ECOIFFIER *et coll* 1968, BELREN *et coll* 1969) but there has been little further mention of venous changes. However VILLAR & HOFFMANN MARTINOT (1951) described a case of a tortuous brachial artery in which large superficial veins were noted in the forearm whereas STAPLE *et coll* (1966) observed that in none of their surgically resected specimens was there any venous enlargement. There has been no description of phlebography in this condition.



a



b

Fig 1 a) Arteriomegaly b) Pelvic phlebography. Normal sized veins with an impression on the outer aspect of the left common iliac vein (arrow) by the left common iliac artery.



a



b

Fig 2 a) Arteriogram showing arteriomegaly of the iliac and femoral arteries b) Normal pelvic phlebography

LERICHE called this condition 'dolicho et mega artere, dolicho et méga-veine'. The name most commonly used by other authors has been *dolicho-mega artere* but some have called it *arteria magna et dolicho* of Leriche, arteriectasis, and buckling or kinking of arteries. We suggest the term *arteriomegaly* as being simple and purely descriptive as the aetiology of the condition is not clearly defined.

Material and Methods In sixteen patients with the radiologic features of arteriomegaly, phlebography of the accompanying veins was performed. Twelve of the patients were being investigated for intermittent claudication but in addition had features such as swelling or ulceration of the ankles or varicose veins for which examination by phlebography was considered necessary.

The four other patients were being investigated for probable obstruction of the venous system and phlebography showed defects in the veins suggesting pressure from glands, or thrombosis, arteriography was then performed to prove that such abnormalities were in fact due to pressure from adjacent enlarged arteries.

In nine cases, impressions on the iliac veins were observed. In one case only, phlebography of the lower limb was performed.

The arteries were examined by translumbar aortography in the prone position in twelve patients, and by the percutaneous catheter technique in the supine position in the remaining four. Pelvic phlebography was performed by percutaneous bilateral femoral vein catheterisation and the films taken with the patients in the same position as for the arteriography. Peripheral lower limb phlebography was performed by our usual technique (BROWSE *et coll* 1967, 1968). In all instances the position of the patient, prone or supine, and the field covered by the films, were identical for both arteriography and phlebography.

DISCUSSION

In none of the sixteen patients examined by phlebography was there enlargement or elongation of the corresponding veins as described by LERICHE.

No phlebographic standards have been established for the normal size of the veins of the pelvis or legs and we did not consider it would be ethical to carry out phlebography in symptomless patients to obtain measurements of this type. However, we considered that the size of the veins in these sixteen patients was within the normal range as judged by the several hundred phlebographic examinations which we have carried out on the pelvic and leg veins (COCKETT *et coll* 1965, 1967, BROWSE *et coll* 1967, 1968, 1969, LEA THOMAS *et coll* 1967, FLETCHER & LEA THOMAS 1968).



a



b

Fig 3 a) Arteriomegaly b) Pelvic phlebography Impression in the right external iliac vein (arrow) by the right external iliac artery



a



b

Fig 4 a) Arteriomegaly b) Pelvic phlebography Large filling defect in the left common iliac vein (arrow) caused by the left common iliac artery

In nine of the sixteen patients there were indentations (Figs 1, 2, 3) in the venous system by neighbouring arteries. Such impressions may be caused even by normal arteries (BARTLEY 1958, LEA THOMAS *et coll* 1968) but because of the enlargement and tortuosity in arteriomegaly these impressions are sometimes of considerable size (Fig. 4).

These arterial impressions or indentations do not accord with the description of the widening and dilatation of the right common iliac vein and inferior vena cava given by LERICHE. It is possible, however, that a high partial obstruction of the inferior vena cava by the dilated right common iliac artery might have caused the appearances although he does not suggest this in his paper. Alternatively, a primary venous disease may have been present.

Two of our patients had venous occlusions, probably unrelated to the arteriomegaly, one due to past deep venous thrombosis and the other from retroperitoneal fibrosis.

Acknowledgements

We wish to thank Mr N. L. Browne, Mr F. B. Cockett, and Prof J. H. Lunnmonth for permission to publish the results of investigations performed on their patients. We should also like to thank Mr T. W. Brandon of the Photographic Department, St Thomas Hospital, for reproducing the illustrations.

SUMMARY

The phlebographic findings in sixteen patients with arterial lengthening and dilatation are presented. None had dilatation or elongation of accompanying veins as described by LERICHE (1943). Impressions on veins by enlarged arteries were observed in nine patients. The term arteriomegaly is suggested for the arterial condition described by LERICHE (1942) and others.

ZUSAMMENFASSUNG

Die phlebographischen Befunde von sechzehn Patienten mit einer arteriellen Verlängerung und Dilatation werden dargestellt. Keiner der Patienten hatte eine Dilatation oder Verlängerung der begleitenden Venen wie sie von LERICHE (1943) beschrieben worden sind. Bei neun Patienten wurde eine Einbuchtung der Venen durch die anliegenden vergrößerten Arterien gefunden. Der Ausdruck Arteriomegalie wird für die von LERICHE (1942) und anderen beschriebenen arteriellen Veränderungen vorgeschlagen.

RÉSUMÉ

Les auteurs décrivent les images phlebographiques chez seize malades présentant des allongements et des dilatations des artères. Aucun n'avait de dilatation ou d'allongement des veines satellites comme LERICHE en avait décrit (1943). Chez neuf malades les artères voisines dilatées marquaient leurs empreintes sur les veines. Les auteurs proposent le terme d'arteriomegalie pour désigner l'état artériel décrit par LERICHE (1942) et par d'autres.

REFERENCES

- ACKERMAN L V and BUTCHER H R Surgical pathology 3rd edition, p 1019 C V Mosby, St Louis 1964
- BARIÉTY M, PAULET J et TERRIS G Les dolicho méga artères Bull Mem Soc Méd Hop Paris 77 (1961), 394
- BARTLEY O Venography in the diagnosis of pelvic tumours Acta radiol 49 (1958), 169
- BRUEN A J, HORT W, KALBFLEISCH H et coll Dysplasia of the systemic and pulmonary arterial system with tortuosity and lengthening of the arteries Circulation 39 (1969) 109
- BROWSE N L, LEA THOMAS M and PIM H P Streptokinase and deep vein thrombosis Brit med J 3 (1968), 717
- — and SOLAN M J Management of the source of pulmonary emboli The value of phlebography Brit med J 4 (1967), 596
- — — and YOUNG A E Prevention of recurrent pulmonary embolism Brit med J 3 (1969), 382
- CASDEN D I and FORMAN D Kinking of the brachial artery New Engl J Med 266 (1962) 1264
- COCKETT F B and LEA THOMAS M The iliac compression syndrome Brit J Surg 52 (1965) 816
- — and NEGUS D Iliac vein compression—its relation to ilio femoral thrombosis and the post thrombotic syndrome Brit med J 2 (1967) 14
- ECOIFFIER J, LAVAL-JEANTET M et KALFFMANN Ciné artériographie fémorale dans les athéromatoses avec dolicho méga artère J Radiol Electrol 49 (1968), 294
- ERTUGRUL A Diffuse tortuosity and lengthening of the arteries Circulation 36 (1967) 400
- FLETCHER E W L and LEA THOMAS M Chronic post thrombotic obstruction of the inferior vena cava investigated by cavography Amer J Roentgenol 102 (1968) 363
- HULTÉN GYLLENSTEN J L, LOFSTEDT S and VON REIN G Observations on generalised arterial ectasis Acta med scand 163 (1959), 125
- LEA THOMAS M and FLETCHER E W L The techniques of pelvic phlebography Clin Radiol 18 (1967), 399
- ANDRESS M R and FLETCHER E W L Arterial impressions in pelvic phlebography Clin Radiol 19 (1968) 404
- FLETCHER E W L, COCKETT F B and NEGUS D Venous collaterals in external and common iliac vein obstruction Clin Radiol 18 (1967) 403
- LEGER L et CERBONNET G Dolicho méga artère Presse méd 58 (1950) 951
- LERICHE R Dilatation pathologique des artères en dehors des anéurysmes vic tissulaire des artères Presse méd 50 (1942) 641
- Dolicho et méga artère dolicho et méga veine Presse méd 38 (1943) 354
- Les symptômes douloureux des dolicho artères Presse méd 55 (1947) 641
- Dolicho méga artère bilatérale fémoropoplitée Presse méd 62 (1954) 1464
- STALLE T W, FRIEDENBERG M J, ANDERSON M S and BUTCHER JR H R Arteria magna et dolicho mf Leriche Acta radiol Diagnosis 4 (1966), 293
- VILLAR J et HOFFMANN MARTINOT R Un nouveau cas de dolicho méga artère Presse med 59 (1951), 100
- WAREMBOURG H NIQUET G, MILLEN J I et coll Les dolicho méga artères Lille méd 8 (1963), 661

DIAGNOSIS OF FLUID IN THE MAXILLARY SINUS

by

N CHIDEREL, C JENSEN, A AXELSSON and N GREBELIUS

Maxillary sinusitis is demonstrated radiographically as thickening of the mucous membrane and often by the presence of fluid. Since the occurrence of fluid is considered to require irrigation, a high degree of diagnostic accuracy is necessary. Essential conditions for the demonstration of fluid are that air is present and that a horizontal beam be used. The frequency of fluid has been investigated at irrigation in radiographically demonstrated sinuses (BALLANTYNE 1946, BUCH 1949, VUORINEN et coll 1962). It was found to occur in 65% to 88% of the pathologic sinuses. BALLANTYNE and BUCH probably did not use a horizontal beam and subsequently could not demonstrate fluid. VUORINEN et coll employed a horizontal beam but failed to report the frequency of fluid demonstrated at the radiologic examination.

The aim of the present investigation was to determine the frequency of fluid in the maxillary sinuses demonstrated radiographically as well as by irrigation, in order to establish the diagnostic reliability of the radiologic demonstration of fluid.

Material and Methods The series comprised 197 patients, 113 females and 84 males, aged 3 to 74 years (mean 31 years). There were 301 maxillary

Submitted for publication 30 August 1969

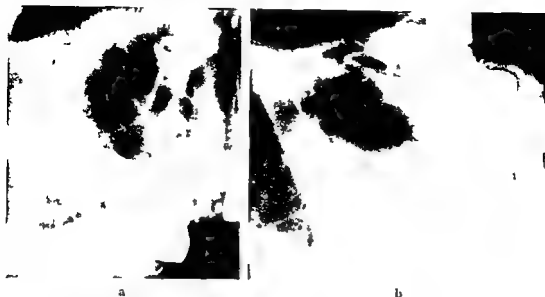


Fig 1 Right maxillary sinus a) Erect. Thickened mucous membrane but not definite fluid level b) Right recumbent position. The outline of the air space has changed indicating the presence of fluid

sinuses, 152 on the right and 149 on the left side, with pathologic changes demonstrated radiographically.

All the patients were examined sitting at the Lysholm skull table with the central beam horizontal. The following four standard projections were used: (1) occipitofrontal, (2) occipitomental, (3) full axial, and (4) lateral. There were 61 patients in whom 88 sinuses presented mucous membrane thickening.

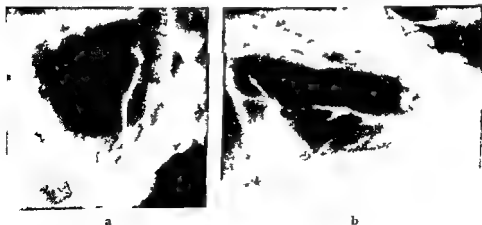


Fig 2 Right maxillary sinus a) Erect. Soft tissue mass on the oblique surface caudally b) Right recumbent position. The fluid level is not clearly seen

Table 1

Frequency of fluid demonstration at irrigation of the maxillary sinuses

	Total sinuses	Fluid demonstrated	
		Number	Per cent
Sinuses containing at least some air	210	128	60
Sinuses without air	83	71	86
Sinuses with cysts or polyps	11	—	—
Total	301	199	66

Table 2

Frequency of fluid in maxillary sinuses containing some air demonstrated on irrigation and at roentgen examination

Type of radiographic examination	Width of mucosal membrane thickening in mm	Number of sinuses	Sinuses with fluid on irrigation		Sinuses with fluid at roentgen examination		Radiologic confidence level, in per cent
			Num-ber	Per-cent	Num-ber	Per-cent	
The four standard projections	1—6 (group A)	108	59	55	10	9	17
	> 6 (group B)	102	69	68	21	21	30
	Total	210	128	61	31	15	24
The four standard projections plus the fifth projection and affected side down	1—6 (group A)	30	19	63	16	53	84
	> 6 (group B)	34	24	71	20	59	83
	Total	64	43	67	36	56	84

but still contained some air, and in whom none of the four standard projections disclosed any fluid, a fifth projection was added, the occipitomental with the head horizontal. Of the eighty-eight sinuses, sixty four were examined with the affected side downwards and twenty-four with the affected side up. Examinations in the fifth projection and in the full axial projection are facilitated by supporting the head on a shelf attached to the skull table as described by TURESON (1948).

Table 3

Frequency of fluid in maxillary sinuses containing air demonstrated at irrigation and at roentgen examination in the four standard projections

Width of mucosal thickening in mm	Number of sinuses	Fluid demonstrated on irrigation		Fluid demonstrated at roentgen examination	
		Number	Per cent	Number	Per cent
1-3	32	13	41	2	6
4-6	76	46	61	8	11
7-9	43	28	65	6	14
10-12	32	21	66	11	34
>12	27	20	74	4	15

The width of the thickened mucous membrane was measured at the middle part of the lateral sinus wall. Fluid was considered to be present when a level was seen in one or more standard projections. The presence of fluid was demonstrated in the fifth projection by comparing the outline of the air space in the sitting and recumbent positions (Figs 1 and 2). All the sinuses were irrigated within half an hour after the roentgen examination. Where no fluid was demonstrated in any of the five projections, but was revealed on irrigation, its amount was noted.

Results

Fluid was demonstrated at irrigation in 66% of the 301 sinuses of the series that had been found radiographically to be pathologic (Table 1). It was present in 86% of the sinuses devoid of air, and in 61% of the sinuses with mucosal thickening but still containing some air. Eight sinuses devoid of fluid on roentgen examination or when irrigated, contained a cyst or polyp.

Sinuses containing at least some air were divided into two groups (Table 2). Group A consisted of those with mucosal thickening of from 1 to 6 mm and group B of those with more than 6 mm thickening. Fluid was demonstrated with the four standard projections in 9% and in 21%, respectively, in the cases of groups A and B, and on irrigation in respectively 55% and 68%. The difference in the radiologic diagnosis between the groups is statistically significant. The figures correspond to a radiologic confidence level of respectively 17% and 30% in the two groups.

The sinuses were further divided into groups with different degrees of

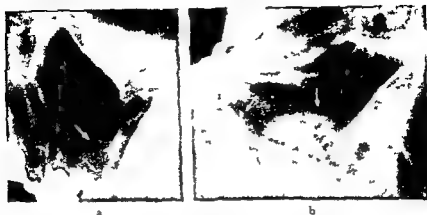


Fig 3 Left maxillary sinus a) Erect Two soft tissue masses the larger one (—) concave upwards at the sinus walls b) Left recumbent position The lesser tissue mass (+) is unchanged indicating mucosal swelling the larger one (—) has moved to the lateral part of the sinus and changed in shape viscid fluid obtained at irrigation

mucosal membrane thickening, and the radiologic findings were again correlated to the irrigation results. The frequency of obtaining fluid at irrigation rose with an increasing degree of mucosal thickening (Table 3). However the radiologic confidence level for fluid demonstrated by the standard projections increased only up to a mucosal width of 12 mm and decreased at higher values.

Fluid was demonstrated radiographically and confirmed by irrigation in 56 % and 67 %, respectively, of the sixty four sinuses examined with the fifth projection and the affected side down (Table 2). This corresponds to a radiologic confidence level for fluid demonstration in groups A and B of respectively 84 % and 83 %. When the maxillary sinuses with fluid demonstrated by the standard projections were added, the confidence levels for groups A and B increased to 87 % and 88 %, respectively (standard deviation 4 %). In four cases fluid was demonstrated on irrigation, but not radiographically in the fifth projection with the affected side down, the amount of fluid in these cases did not exceed 5 ml. The twenty four sinuses examined with the fifth projection but with the affected side up had a radiologic confidence level of fluid demonstration of 50 %. The difference between the results obtained with the affected side directed down and up is statistically significant. The fluid presented an upwards concave outline near the sinus wall in all cases except two in which the outline was convex upwards (Fig 3), in both these cases a mucous, viscid fluid was obtained on irrigation. No statistical difference was recorded



Fig 4 Left maxillary sinus. a) Erect Soft tissue mass caudally with horizontal outline and convex upwards at the sinus walls (arrow) b) Left recumbent position The mass represents a soft mobile polyp with a narrow pedicle (arrow)

as regards fluid demonstrated in women and men or between the right and left maxillary sinuses

Discussion

Fluid levels in an antrum are readily disclosed in standard projections when the amount of fluid is considerable but may be absent when the amount is small. The present investigators failed to demonstrate fluid in about three quarters of the sinuses containing air. The reason may have been that small levels were present at the bottom of the sinus, which are often concealed by the alveolar process and by the teeth. As TURESSON pointed out, a fluid level in the frontal sinuses may be demonstrated in an occipitofrontal projection with the head horizontal and one side down while a level in the sphenoidal sinuses should be demonstrated in the lateral projection with the head horizontal and the back of the neck down. To increase the confidence level for demonstration of fluid in the maxillary sinuses the occipitomental projection with the head tilted in one or both directions should be employed (HODGSON 1931). Small amounts of fluid in the maxillary sinuses have been demonstrated in an occipitomental projection with the head horizontal and one side down (CLAUS 1926, SAMUEL 1953). No investigation appears however to have been published previously regarding the frequency of fluid diagnosed radiologically by the latter or any other method. The interval between the roentgen examination and the irrigation has in



FIG. 5. Left maxillary sinus. a) Erect. Mass caudally with a horizontal outline. b) Horizontal position. The appearance, and

previous papers either not been stated or has amounted to several days. A high degree of agreement between the radiologic and the irrigation findings was established in the present investigation by the fact that all the irrigations were made within half an hour of the roentgen examination.

Fluid was produced at irrigation in 88 % by BALLANTYNE, in 65 % by BLICH, in 77 % by VLORINEN et coll and in 66 % of the maxillary sinuses with radiographic changes in our series. The differences probably depend on a higher frequency of sinuses with a minor degree of mucosal thickening in our material and in BLICH's as compared with the other two series. The frequency of fluid is lower in such sinuses than in those with more marked mucosal thickening. It was found in the present investigation that the radiologic confidence level for the demonstration of fluid in maxillary sinuses containing at least some air was 24 % where the four standard projections were concerned. When the examination was extended with the occipitomental projection, with the head in horizontal position and the affected side down, the diagnostic confidence level increased to 88 %. Some of the diagnostic difficulties at examinations with the affected side up may depend on the irregular shape of the medial maxillary sinus wall and the fact that the posterior ethmoidal cells partly conceal the medial aspect of the maxillary sinus. These facts may explain why small differences in the outline of the air space are easier to detect in the lateral than in the medial part of the sinus.

In the two maxillary sinuses containing a mucous, viscid liquid, the fluid level near the sinus walls had an upwards convex outline. A similar appearance



Fig 4 Left maxillary sinus a) Erect Soft tissue mass caudally with horizontal outline and convex upwards at the sinus walls (arrow) b) Left recumbent position The mass represents a soft mobile polyp with a narrow pedicle (arrow)

as regards fluid demonstrated in women and men or between the right and left maxillary sinuses

Discussion

Fluid levels in an antrum are readily disclosed in standard projections when the amount of fluid is considerable but may be absent when the amount is small. The present investigators failed to demonstrate fluid in about three quarters of the sinuses containing air. The reason may have been that small levels were present at the bottom of the sinus, which are often concealed by the alveolar process and by the teeth. As TURESSON pointed out, a fluid level in the frontal sinuses may be demonstrated in an occipitofrontal projection with the head horizontal and one side down, while a level in the sphenoidal sinuses should be demonstrated in the lateral projection with the head horizontal and the back of the neck down. To increase the confidence level for demonstration of fluid in the maxillary sinuses the occipitomental projection with the head tilted in one or both directions should be employed (HODGSON 1931). Small amounts of fluid in the maxillary sinuses have been demonstrated in an occipitomental projection with the head horizontal and one side down (CLAUS 1926, SAMUEL 1953). No investigation appears however to have been published previously regarding the frequency of fluid diagnosed radiologically by the latter or any other method. The interval between the roentgen examination and the irrigation has in

FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY (DIRECTOR B. NORDEN-
STROM), KAROLINSKA SJUKHUSET, STOCKHOLM, THE DEPARTMENT OF MEDICAL
ENGINEERING (DIRECTOR B. JACOBSSON), KAROLINSKA INSTITUTET, STOCKHOLM,
AND THE RESEARCH LABORATORY OF MEDICAL ELECTRONICS (DIRECTOR H. WALL-
MAN), CHALMERS INSTITUTE OF TECHNOLOGY, GOTHENBURG, SWEDEN

ELIMINATION OF BLUR IN LINEAR TOMOGRAPHY

by

PALL EDHOLM and LARS QUIDING

The interpretation of the diagnostic content of a linear tomogram is complicated by the presence of blur. This is the main reason for other types of tomography being preferred, where practicable, as for instance those based on circular and hypotrochoidal motion in which the blur is less marked. Linear tomography possesses however the advantages that the apparatus is inexpensive and simple in design, that a high level of precision can be obtained and that the exposure times are short, the ordinary roentgen unit can moreover often be adapted for linear tomography. As linear tomography is the only practicable technique in neuroradiologic examinations requiring certain projections, a method of eliminating blur from linear tomograms seems to be urgently needed.

Linear blur. A tomogram consists in the main of two groups of components, the details in the tomographic layer and those outside it (Fig. 1a). The former are sharp whereas the latter are blurred in the direction of motion, so that the contrast is reduced to a point where details usually cannot be perceived. Certain details are resistant however and remain visible as long stripes with

Submitted for publication 17 December 1969

may however also represent a soft polyp or a cyst containing fluid under low tension. With the fifth projection added, the observation of a change in shape and position of the air is often useful for a differentiation between viscid fluid polyps and cysts (Figs 3, 4 and 5).

It is interesting to note that in the material of VUORINEN *et coll*, fluid was disclosed on irrigation in 6 % of the radiographically normal maxillary sinuses. To judge by the findings in our investigation, those fluid contents could probably have been demonstrated with the fifth projection. It thus appears that the occipitomental projection with the head horizontal and the affected side down can be recommended as a routine when the mucous membrane is thickened and some air remains and when the standard projections have not disclosed any fluid.

SUMMARY

The frequency of fluid in the maxillary sinuses demonstrated at roentgen examination in a material of 197 cases is recorded. The method of showing the fluid levels, its confirmation by irrigation, and the differential diagnosis are discussed at length.

ZUSAMMENFASSUNG

Die Frequenz der Nachweisbarkeit von Flüssigkeit in den Oberkieferhöhlen wurde bei Röntgenuntersuchungen von 197 Fällen festgestellt. Es wird detailliert erörtert wie die Flüssigkeitsspiegel am besten demonstriert werden können, auch anhand der Irrigationspunction. Die Differentialdiagnose wird diskutiert.

RÉSUMÉ

Les auteurs ont noté sur 197 malades la fréquence des signes radiologiques d'épanchement liquide dans les sinus maxillaires. Ils étudient assez longuement la méthode pour mettre en évidence le liquide pour confirmer sa présence par lavage et examinent le diagnostic différentiel.

REFERENCES

- BALLANTYNE J. C. On the relationship between radiological appearances and proof puncture findings in suspected cases of infection of the maxillary antrum. *J. Laryng.* 61 (1946) 306.
 BUCH A. Non diagnosed maxillary sinusitis. *Acta oto laryng.* (1949) Suppl. No. 77.
 CLAUS G. Über die Gestalt der Flüssigkeitsslinien auf Röntgenplatten erkrankter Nasennebenhöhlen. *Fortschr. Röntgenstr.* 34 (1926) 262.
 HODGSON H. The radiography of the accessory nasal sinuses. *Brit. J. Radiol.* 6 (1931) 421.
 SAMUEL E. The opaque maxillary antrum. *Brit. J. Radiol.* 26 (1953) 465.
 TURESSON D. The roentgen diagnosis of fluid in the frontal and sphenoidal sinuses. *Acta radiol.* 29 (1948), 215.
 VUORINEN P., KAUPPIA A. and PULKKINEN K. Comparison of results of roentgen examination and puncture and irrigation of the maxillary sinuses. *J. Laryng.* 76 (1962) 359.



Fig 2 Photographs of the television monitor with a frontal tomogram of the skull. The lines of the television image are vertical. a) Untreated tomogram. b) Duplicate of the tomogram after passing through the low pass filter. c) Difference image of (a) and (b).

eliminates the sharp details while leaving the stripes almost unchanged. The copy will thus be a negative of the linear blur, and when it is placed on the tomogram the stripes in the two films will cancel each other out. The sharp details in the tomogram have no counterparts in the copy and will therefore be reproduced as before but undisturbed by linear blur.

The displacement of the contact copy during exposure calls for precision, and is not easily done manually. An apparatus for effecting this smoothly and under control has therefore been designed and constructed. The most suitable displacement distance has been found to be about 2 cm.

If the tomogram contains linear blur in areas differing greatly in density the blur will be underexposed in some parts of the copy and incompletely eliminated when the copy and tomogram are superimposed. The tomogram should then be combined first with a negative having multidirectional blur. The contrast is evened out in this manner so that in the final copying the exposure will be approximately the same for all the blur (Fig 1b). All the stripes can then be reproduced in the copy and completely eliminated.

Sharp copy. With this method an ordinary sharp negative copy of the tomographic film is produced. Both images will thus contain sharp and blurred details and if they are combined in the usual way a uniformly grey image will result. If the copy and the tomogram are displaced a short distance in relation to each other, in the direction of the stripes, the sharp details will again be seen, though they will not have the usual appearance but give the impression

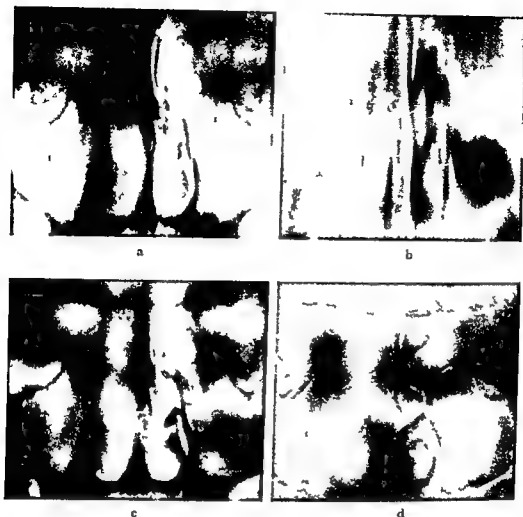


Fig 1 Carcinoma of the right maxillary sinus with destruction of the medial wall
 a) Tomogram b) Copy with linear blur in which the contrast has been evened out
 c) Combination of (a) and (b) d) Combination of (a) and a sharp copy displaced
 in the direction of the linear blur

diffuse ends and sharp lateral contours parallel to the direction of motion. The resistance of detail to blurring is dependent on its contrast and its dimension in the direction of motion.

Photographic methods Photographic methods of eliminating blur are based on subtraction, a transparent contact copy of the tomogram being subtracted from the tomogram itself. Two methods will be described.

Copy with linear blur Blur is produced in a contact copy by moving it in the direction of the stripes at a constant speed during the copying process. This

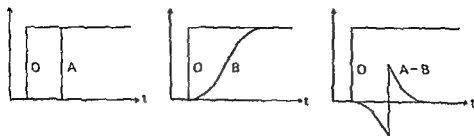


Fig 5 Appearances of the signal at the various points in fig 4 O — untreated λ — delayed, B — after passing through a low pass filter, A-B= subtraction

of this derivative, while the stripes have low values. Areas with positive and negative derivatives are reproduced in light and dark, respectively, while areas where the derivative is zero are reproduced as a neutral grey.

The optimal displacement between copy and original has been found to be a little less than one millimetre. The results were poorer than with the former method, the image being ill defined and difficult to interpret in the direction of displacement.

Electronic methods. A television image is composed of lines that are scanned in succession and can thus easily be modified in the direction of the lines. If a tomogram is placed in front of a television camera, with the stripes parallel to the scanning lines, the sharp image details will give high frequencies in the television signal while the blur will produce low frequencies. This fact affords several possibilities of eliminating the linear blur by means of filters. Three methods will be described.

Subtraction with two cameras. The tomogram is placed under one camera and a duplicate of the tomogram under the other camera. The films are orientated so that the stripes run parallel to the lines of the television image. The signal from one camera is passed through a filter that eliminates the high signal frequencies and leaves the low frequencies unaffected, the sharp details are thus eliminated and the stripes remain unchanged. This signal, which now consists chiefly of blurred detail, is subtracted from the unfiltered signal produced by the other camera. The filter incurs a time delay, and this is compensated for by moving one of the images over a corresponding distance parallel to the lines of the television image. The difference signal produces an image of only the sharp details — the stripes are eliminated. The procedure is illustrated in Fig 2. Two disadvantages of this two-camera method are its complicated



Fig 3 Images from the monitor in the same case as in fig 1 a) Untreated tomogram b) After passing through a high pass filter

of a relief viewed by oblique illumination. The stripes, on the other hand, because their ends are diffuse, will not be seen at all (Fig 1d)

This method gives in effect the derivative of the density relief in the direction of the displacement. The sharp details have high positive and negative values

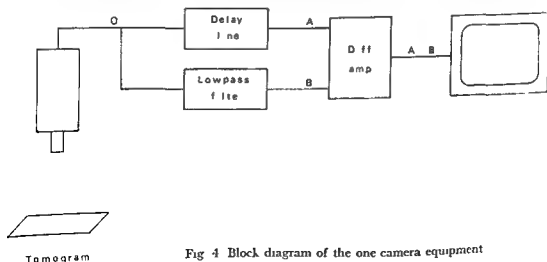


Fig 4 Block diagram of the one camera equipment

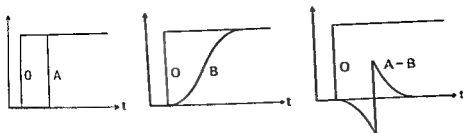


Fig 5 Appearances of the signal at the various points in fig 4 O — untreated, 1 — delayed, B — after passing through a low pass filter, A-B = subtraction

of this derivative, while the stripes have low values. Areas with positive and negative derivatives are reproduced in light and dark, respectively, while areas where the derivative is zero are reproduced as a neutral grey.

The optimal displacement between copy and original has been found to be a little less than one millimetre. The results were poorer than with the former method, the image being ill defined and difficult to interpret in the direction of displacement.

Electronic methods A television image is composed of lines that are scanned in succession and can thus easily be modified in the direction of the lines. If a tomogram is placed in front of a television camera, with the stripes parallel to the scanning lines, the sharp image details will give high frequencies in the television signal while the blur will produce low frequencies. This fact affords several possibilities of eliminating the linear blur by means of filters. Three methods will be described.

Subtraction with two cameras The tomogram is placed under one camera and a duplicate of the tomogram under the other camera. The films are orientated so that the stripes run parallel to the lines of the television image. The signal from one camera is passed through a filter that eliminates the high signal frequencies and leaves the low frequencies unaffected, the sharp details are thus eliminated and the stripes remain unchanged. This signal, which now consists chiefly of blurred detail, is subtracted from the unfiltered signal produced by the other camera. The filter incurs a time delay, and thus is compensated for by moving one of the images over a corresponding distance parallel to the lines of the television image. The difference signal produces an image of only the sharp details — the stripes are eliminated. The procedure is illustrated in Fig 2. Two disadvantages of this two camera method are its complicated

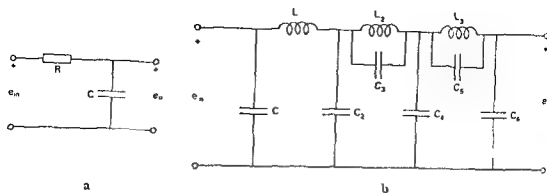


Fig 6 a) A simple low pass filter b) The Thomson low pass filter

nature — the tomogram must be duplicated — and the fact that the equipment is expensive

One camera with a high pass filter A high pass filter inserted in an ordinary television circuit for transmission of roentgenograms damps low signal frequencies, whereas the high frequencies are unaffected, that is to say, the linear blur is reduced and the sharp details are unchanged. To eliminate blur completely with a simple high pass filter, a filter that will let pass only the highest signal frequencies must be chosen. A contour image in which it is difficult to relate the contours to the anatomic details will then be obtained (Fig 3).

This procedure is simple, all that is required apart from the adjustments normally performed in the TV transmission of ordinary roentgenograms is that the tomogram should be placed so that the stripes become parallel to the lines of the television image.

One camera with low pass filter and delay line The simplicity of the one camera procedure may be combined with the good image quality of the two camera method as is schematically illustrated in Fig 4. The signal from the television camera is fed to two circuits in parallel, in one of which the sharp details are eliminated by a low pass filter that suppresses the high frequencies and leaves the stripes unchanged. In the other circuit the signal passes untreated through a device that delays it for the time that the other signal is held up by the filter, the correct time relationship between the two signals is thus retained. The filtered signal is then subtracted from the delayed signal. A sharp contour in the tomogram gives rise to signals as in Fig 5, where (O), (A) and (B) are the signals from the television camera, the delay circuit and the filter, respectively, and (A—B) is the signal seen on the television monitor. In the elimination of the linear blur, the choice of filter is not a particularly

critical factor, whereas the reproduction of the sharp details is largely dependent on the properties of the filter. The desired sigmoid output signal in Fig 5 B can be produced sufficiently accurately via a series of filters connected in cascade as in Fig 6a, or by a Thomson filter as in Fig 6b.

Discussion

The part of the body depicted in a tomogram may be regarded as consisting of a number of parallel layers, one of which is the tomographic layer. The tomogram is a summation of all these layers. The tomographic layer is fully defined, but the others suffer loss of their high spatial frequencies. It appears as if all the layers, except the tomographic one, pass through a filter that only transmits low frequencies. The greater the distance between the tomographic layer and any other layer, the greater the lost frequency range.

Tomography may be regarded as a method that provides a selective picture of the tomographic layer by filtering out the rest of the body; the effect is incomplete, however, because only the high frequencies are suppressed, the low frequencies being represented as blur.

In effect, both the methods that have been described for eliminating linear blur, the photographic and the electronic, amount essentially to refiltering the tomogram so that the high frequencies are unmodified and the low frequencies are suppressed. This results in total elimination of the undesirable layers and isolation of the tomographic layer. The low frequencies in this layer are however also filtered out. The effect of this will be that any true detail in the tomographic layer, with form and position similar to a tomographic stripe, will disappear. For this to happen, the detail must however be exactly aligned with the direction of tomographic motion.

SUMMARY

Various methods of eliminating blur in linear tomography are discussed. Television circuits which include filters passing high frequencies and suppressing the low frequencies that cause the blur are described.

ZUSAMMENFASSUNG

Versuche wurden angestellt, um zu ermitteln wie Unschärfe bei linearer Tomographie vermieden werden kann. Es wurden Fernsehketten mit Filtern benutzt, die Hochfrequenzen passieren lassen und die die Niedrigfrequenzen, die Unschärfe verursachen, unterdrücken.

RÉSUMÉ

Les auteurs examinent les différentes méthodes qui éliminent le flou en tomographie linéaire. Ils décrivent des circuits de télévision comprenant des filtres laissant passer les hautes fréquences et arrêtant les basses fréquences qui causent le flou.

Book review

DOSSAGE NON DESTRUCTIF DE LA COMPOSANTE MINÉRALE DU TISSU OSSEUX PAR DENSITOMÉTRIE RADIOGRAPHIQUE. Par W. Mouvet. Éditions Arscia, Bruxelles 1967

This book is another approach to the difficult problem of radiographic determination of mineral content of bone. The author has thoroughly analysed the physical phenomena involved, and the detailed introduction deals with the absorption of roentgen rays, film emulsion and the theory of densitometry. The effect of the non random distribution of absorbing components as a potential source of error (ORNSTEIN, *Lab Invest* 1 (1952), 250) has not been mentioned, but because of the relatively small focal spot, this error probably does not affect the results of the present method.

The author uses a special stand consisting of two parallel plates for radiography of the bones. The fine-grain nonscreen roentgen film, the reference systems and an aluminium exposure control plate are placed on the lower one. The upper plate is made up of a wooden frame, lead bars embedded in perspex and a removable lid. The amount of secondary radiation can be assessed with the aid of the lead bars. The mineral content of the bone to be examined is expressed as the mean thickness of aluminium, corrections being made for secondary radiation and taking the thickness of the bone and the surrounding soft parts into account. The result calculated gives the mineral content of a bone measured transversely in a tracing path.

The series examined by the author consists of humeri, radii, ulnae, scaphoids and finger phalanges. The bones were sliced according to the densitometric tracing paths, and the results of densitometry compared with those of a chemical analysis. A significant statistical correlation was established.

The organic fraction and water in the bone tissue usually represent more than half of its weight and vary considerably according to age. As pointed out by OMVALL (1958) the ratio between the amount of bone salt per unit of area and the equivalent amount of reference material (aluminium) is dependent on the ratio between the weights of bone salt and organic material and water. This is a severe handicap affecting all radiographic methods in which heterogeneous radiation is used. The procedure employing almost monochromatic ¹²⁵I radiation (CAMERON *et coll*, *Science* 142 (1963), 270, *Invest Radiol* 3 (1968) 141) is theoretically more satisfactory and apparently gives more reliable results (MAZESS *et coll*, *Science* 145 (1964), 388).

A bone is a biologic as well as a human skeleton unit and measurements made along a certain tracing path of a bone do not necessarily dependably reflect the mineral content of the bone in question or that of the entire skeleton (HELELA & VIRTAMA, *Invest Radiol* 3 (1968), 103). Measurements should therefore be made along numerous tracing paths of different bones which makes the densitometric method cumbersome and time consuming. The measurement of the cortical bone (VIRTAMA & HELELA, *Acta radiol* (1969) Suppl. No. 293) may in the comparison of relatively large groups of population and in clinical studies furnish a practical alternative to more accurate but tedious densitometric methods. The choice of the procedure to be used depends on the special problem to be examined in each individual case.

The book is well-written and gives a good survey of the factors affecting the densitometric determination of the mineral content of bone. It can be recommended as a reliable guide to the special problems involved in radiographic measurement of bone minerals. The method presented is certainly suited, e.g. for control investigations of individual bones, and may probably also be trusted in comparing the mineral contents of individual bones.

Pekka Virtama

EFFECT OF LOCAL INTRAARTERIAL ADMINISTRATION OF BRADYKININ AND HYDERGINE IN OBSTRUCTIVE ARTERIAL DISEASE

by

UVO ERIKSON

The technique in peripheral arteriography is still far from satisfactory. The conventional method of catheter insertion and subsequent injection of contrast medium often fails to give good result.

The relation between the blood flow and the peripheral contrast filling has been discussed by ERIKSON (1965), who found that a low blood flow was related to poor peripheral filling at arteriography, proposed the use of local arterial injection of vasodilators, and chose bradykinin. VOGLER (1953) has recommended intraarterially administered hydergine for obtaining better contrast filling in patients with varicosis. Bradykinin is an agent with a short decomposition time while hydergine has a long decomposition time.

Contrast filling of the peripheral arteries did not always improve after local arterial injection of bradykinin in some patients with extensive occlusion of the femoral artery. Possibly the transit time was too long and the shunt effect in the thigh, above the occlusion, too strong, so that the concentration of bradykinin in the small arteries of the calf became relatively low and the vessels did not dilate within the short time of action of the bradykinin. Another possible explanation

From The Departments of Diagnostic Radiology (Director Prof H. Lodin) and Clinical Physiology (Director Prof G. Strom), The University Hospital, Uppsala, Sweden. Submitted for publication 10 December 1969.

Table

Measurements of blood flow at rest and after injection of bradykinin and hydergine in lucite patients with arteriographic results indicated by 0, no change, — decreased contrast filling of arteries, and + improved contrast filling — The code for the diagnoses is given under the heading 'Material and Methods'

Case	Age	Sex	Diagnosis		Place of catheter tip	Blood flow at rest ml/100 ml min	
			Right leg	Left leg		Right leg	Left leg
1	53	M	4	1	Aorta	40	50
2	76	F	2	4	Aorta	30	23
					Mean	35	37
					Range	30—40	23—50
3	75	M	0	0	Aorta	61	63
			Injected leg	Control leg		Injected leg	Control leg
4	68	M	4	4	Femoral art	12	04
5	52	M	1	4	Femoral art	10	06
6	73	F	1	1	Femoral art	30	35
7	66	F	4	—	Femoral art	22	21
8	43	M	0	4	Femoral art	34	22
					Mean	22	17
					Range	10—34	04—35
9	52	M	0	0	Femoral art	36	22
10	50	F	0	0	Femoral art	40	19
11	26	M	0	0	Femoral art	23	20
12	32	F	0	0	Femoral art	—	—
					Mean	33	20
					Range	23—36	19—22

could be diminished reactivity of the resistance vessels to bradykinin due to constant and marked local metabolic vasodilatation

Hydergine (Sandoz AG, Basel) has a longer half-life and is commonly used in the treatment of peripheral blood flow disturbances. The hydrated ergot alkaloids dihydroergocornine, dihydroergocristine and dihydroergocryptine have both a vasodilative effect, due to a sympatholytic action, as well as a number of other effects on the vessel walls of vasoconstrictive nature (EICHLER & HEINZEL 1954). The skin temperature is considered to increase after administration of hydergine (FRANK et coll 1956). VÖGLER (1953) stated that arteriovenous anastomoses frequently occurred in leg ulcers, they were closed by intraarterial administration

Table (cont.)

Maximal change of blood flow in ml/100 ml min after injection of						Effects upon the arteriogram from	
Bradykinin			Hydergine			Brady kinin	Hyder gine
Right leg	Left leg	Dose µg/min	Right leg	Left leg	Dose mg		
0.9	0.4	19	-1.3	-1.8	0.6	+	-
2.0	0.9	17	-0.2	0	0.6	+	-
1.5	0.7	18	-0.8	-0.9	0.6		
0.9-2.0	0.4-0.9		-1.3-0.2	-1.8-0			
13.4	24.2	10	-1.3	-0.5	1.2	+	0
Injected leg	Control leg		Injected leg	Control leg			
30.8	1.0	10	-0.2	1.6	0.3	+	0
14.4	0.2	10	0.3	0.2	1.2	+	-
27.4	2.4	10	0.7	0.5	0.6	+	-
0	0	10	0.2	-0.7	0.6	0	-
18.4	-0.2	10	-0.4	-1.5	0.6	+	-
18.2	0.7	10	0.2	0	0.6		
0-30.8	-0.2-2.4	10	-0.4-0.7	-1.5-1.6	0.3-1.2		
-	-	10	-	-	0.9	+	-
0.2	-0.2	10	-0.8	-0.6	0.6	0	0
10.3	-1.3	10	-0.5	0.8	0.6	+	0
-	-	17	-	-	0.6	+	0
5.3	-0.8	17	-0.7	0.1	0.7		
0.2-10.3	-1.3-0.2		-0.8-0.5	-0.6-0.8			

of hydergine, with a consequent redistribution of blood to peripheral areas previously undersupplied. This effect in particular, and to some extent the vasodilative effect, have been suggested to explain the fact that oral doses of hydergine shorten the healing time in ischaemic ulcers of the lower limb (HAEGER 1965).

The effect of vasodilative substances on the arteriograms of subjects with intact blood vessels and patients with arteriosclerosis does not seem to have been investigated previously, and a comparative investigation of the effects of bradykinin and hydergine therefore seemed indicated.

Material and Methods Twelve patients were investigated, five of whom were women aged 32 to 76, and seven were men aged 26 to 73 years. One patient

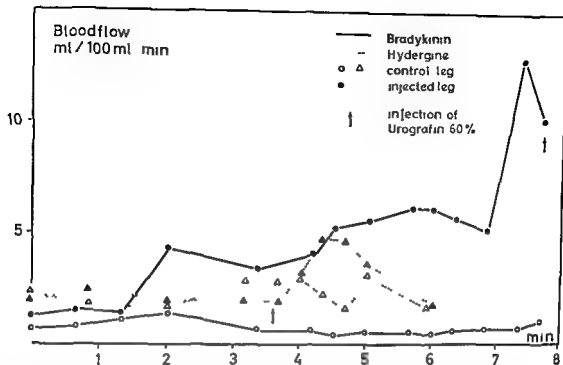


Fig 1 Case 11 Male, aged 26 with posttraumatic narrowing of the popliteal artery. Bradykinin in a dose of $10 \mu\text{g}/\text{min}$ induced increased blood flow which reached a maximum after 7 minutes. Hydergine, in a dose of 0.6 mg , had no effect on the flow. The arrows indicate the time of contrast medium injection. The short increase in flow that can be seen after injection of the contrast medium in the hydergine treated leg is typical of such an injection and within ordinary limits (Cf fig 3)

(Case 9), aged 52, had arterial hypertension ($210/120 \text{ mm Hg}$) and weighed 81 kg . The other patients had normal blood pressures and weights. Seven patients had arteriosclerosis and four had intact arteries. One patient (Case 11) had undergone operation before the investigation (see Table).

The examinations were always performed in the morning in a laboratory with a room temperature of about 23°C . The patients were premedicated with 0.1 g pentymal and subjected to measurement of the resting blood flow in the supine position under the influence of test drugs and arteriography.

The blood flow in both lower legs was measured by venous occlusion plethysmography according to a method described by DOHN (1956) and GRAF (1964).

Catheters were introduced percutaneously for arteriography via the femoral artery. In nine patients the tip of the catheter was located about 6 cm above the site of puncture, which was anaesthetized locally. In three patients the catheter was inserted to a point about 5 cm above the aortic bifurcation (see Table).

Preliminary arteriography was performed without any preceding injection of test drugs. The blood flow was usually measured during arteriography. The

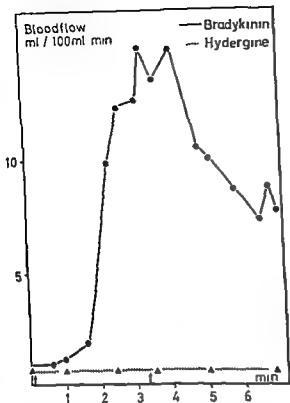


Fig 2 Case 5 Male aged 52, with bilateral arteriosclerosis. The blood flow began to increase 2 to 3 minutes after the start of an injection of bradykinin in a dose of 10 μ g/min. After injection of 0.6 mg hydergine at 0 min and 3.3 minutes (arrow) there was no effect on the blood flow. The arteriographies were performed at 7 minutes.

patient then rested for 30 minutes, after which bradykinin (Sandoz AG, Basel) dissolved in physiologic saline was infused via the catheter in varying doses of up to 30 μ g per minute. The infusion in nine patients was given into one leg while the other leg served as control. In three patients bradykinin was infused into the aorta, and thus affected both legs.

When the patient had a sensation of warmth and flushing of the skin, which sometimes did not occur until about 10 minutes after the start of the infusion, further arteriography was performed. The injection of contrast medium, which was given through the same catheter as had been used previously for the bradykinin infusion, had to be performed as rapidly as possible because of the short decomposition time of this drug. The contrast medium was injected within 10 seconds of the end of the bradykinin infusion.

The patient then again rested for 30 minutes and thereafter was given a slow intraarterial injection of 0.3 to 1.2 mg hydergine. Further arteriography was carried out, under otherwise identical conditions, between 3 and 5 minutes later.

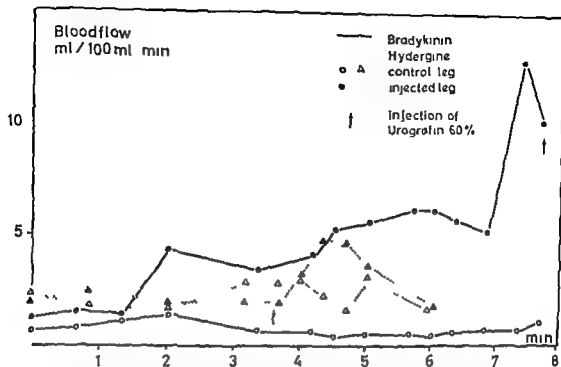


Fig 1 Case 11 Male, aged 26, with posttraumatic narrowing of the popliteal artery. Bradykinin in a dose of 10 μ g/min induced increased blood flow which reached a maximum after 7 minutes. Hydergine, in a dose of 0.6 mg, had no effect on the flow. The arrows indicate the time of contrast medium injection. The short increase in flow that can be seen after injection of the contrast medium in the hydergine treated leg is typical of such an injection and within ordinary limits (Cf fig 3).

(Case 9), aged 52, had arterial hypertonia (210/120 mm Hg) and weighed 81 kg. The other patients had normal blood pressures and weights. Seven patients had arteriosclerosis and four had intact arteries. One patient (Case 11) had undergone operation before the investigation (see Table).

The examinations were always performed in the morning in a laboratory with a room temperature of about 23° C. The patients were premedicated with 0.1 g pentymal and subjected to measurement of the resting blood flow in the supine position under the influence of test drugs and arteriography.

The blood flow in both lower legs was measured by venous occlusion plethysmography according to a method described by DOHN (1956) and GRAF (1964).

Catheters were introduced percutaneously for arteriography via the femoral artery. In nine patients the tip of the catheter was located about 6 cm above the site of puncture, which was anaesthetized locally. In three patients the catheter was inserted to a point about 5 cm above the aortic bifurcation (see Table).

Preliminary arteriography was performed without any preceding injection of test drugs. The blood flow was usually measured during arteriography. The

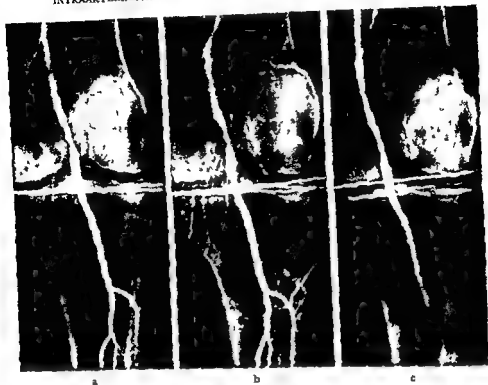


Fig 3 Case 11 Arteriography without drug (a), after injection of bradykinin (b) and after injection of hydergine (c) (Cf fig 1)

very slightly after the bradykinin injection. In two other patients with intact blood vessels the blood flow was not measured. In Cases 10 and 11, hydergine resulted in no definite change in the flow. In all nine patients, bradykinin usually produced improvement of the peripheral contrast filling. Hydergine resulted in no or decreased filling of the peripheral arteries (Fig 3).

None of the patients experienced discomfort after the injection of bradykinin or hydergine. No change in the blood pressure was observed.

Discussion

The peripheral contrast filling in arteriography may be difficult, particularly with a poor blood flow. Bradykinin often induces an increase in flow, thus improving the filling (Erikson, 1965). Intraarterial injection of bradykinin into the femoral artery in arteriosclerotic patients also produced an increase of the flow in the calf, and the filling increased in four out of five patients.

Hydergine, on the other hand, had relatively little influence on the flow and

For the arteriographies, 20 to 30 ml Isopaque 60 % or Urografin 60 % were injected with an automatic pressure syringe (5 kp/cm²). The exposure frequency was 1/second. The film-focus distance and other technical factors were identical for all the patients.

The arteriographic findings were graded as regards changes in the superficial femoral artery and the popliteal artery (DELIUS & ERIKSON 1969), as follows:

Grade 0 — No marked change in the lumen

" 1 — Marked changes at one or several sections within the artery but no more than 50 % stenosis in the lumen

" 2 — Stenosis of more than 50 % in one section but no total occlusion

" 3 — Stenosis of more than 50 % in two or more sections but no total occlusion

" 4 — Total occlusion of at least one section of the artery

Results

The blood flow was measured continuously during the infusion of bradykinin, up to about 2 minutes after the injection of contrast medium and for about 45 minutes after the injection of hydergine.

After commencement of the bradykinin infusion, the blood flow increased within 2 to 7 minutes to relatively high values (Figs 1 and 2). When the flow had reached these values the patients had a sensation of warmth in the sole of the foot. After completion of the bradykinin infusion the blood flow decreased rapidly (within 20 to 40 seconds) to the resting values. The contrast medium was therefore always injected within a very short period following the end of the bradykinin infusion.

Infusion of hydergine had very little effect on the flow (Figs 1 and 2).

The results are presented in a Table, which includes age, sex, diagnoses and doses, as well as catheter positions, resting blood flows and maximal changes in flow after injection of the vasoactive substances.

Bradykinin in the two patients with arteriosclerosis resulted in a small degree of vasodilatation when injected into the aorta. In the patient with intact blood vessels (Case 3) marked vasodilatation was observed. The peripheral demonstration of the arteries was improved in all the patients. A slight reduction of the flow occurred in all the three patients in whom hydergine was injected into the aorta.

In five patients with arteriosclerosis, the blood flow increased considerably when bradykinin was injected into the femoral artery, in these patients, hydergine had little effect on the flow. In one patient with intact blood vessels (Case 11) (Figs 1 and 3), the flow increased after the bradykinin injection and decreased slightly after the hydergine injection. In a woman (Case 10), the flow increased

ZUSAMMENFASSUNG

graphie ist als Hydergin. Hydergin versagt bei der Anwendung sowohl bei normalen als auch bei arteriosklerotischen Arterien der unteren Extremitäten.

RÉSUMÉ

L'auteur a étudié l'effet d'agents vasodilatateurs sur les artériographies de douze sujets ayant des vaisseaux intacts ou artérioscléreux. La bradykinine est préférable à l'hydergine comme agent vasodilatateur administré par voie intra artérielle en artériographie. L'hydergine semble dépourvue d'effets vaso-dilatateurs sur les membres inférieurs artérioscléreux ou non artérioscléreux.

REFERENCES

- DELLUS W. and ERIKSON U.: Correlation between angiographic and haemodynamic findings in occlusions of arteries of the extremities. *Vasc Surg* 3 (1969), 201
- DOHN K.: Plethysmographs usable during functional states for recording volume changes in ml per 100 ml of extremity. *Rep Steno Hosp (Kbh)* (1956), 147
- EICHLER O. und HEINZEL J.: Die Behandlung peripherer Durchblutungsstörungen mit Hydergin. *Arzneimittel Forsch* (1954), Beibef. 4
- EMMENEGER H. and MEIER RUGE W.: The actions of Hydergine on the brain. A histochemical, circulatory and neurophysiological study. *Pharmacology* 1 (1968), 65
- ERIKSON U.: Peripheral arteriography during bradykinin induced vasodilatation. *Acta radiol* Diagnosis 3 (1965), 193
- : Circulation in traumatic amputation stumps. An angiographical and physiological investigation. *Acta radiol* (1965) Suppl. No. 238
- FRANK N., NAKANO J. and BALDINI G.: The effect of Hydergine on peripheral vascular disease. *J med Soc N J* 53 (1956), 12
- GERARD J., BÉs A., RASCOL A. et coll.: Mesure du débit sanguin cérébral au krypton 85. Quelques applications physiopathologiques et cliniques. *Rev neurol* 108 (1963), 542
- GILLESPIE J. A.: The case against vasodilator drugs in occlusive vascular disease of the legs. *Lancet* 1959 II, p. 995
- GRAF K.: Auswertung und Messfehler okklusionsplethysmographischer Durchblutungsregistrierungen. *Acta physiol scand* 60 (1964), 120
- HÄGER K.: Ischaemic ulcers of the lower limb. *Acta chir scand* 53 (1965), 12
- SELDINGER S. I.: Catheter replacement of the needle in percutaneous arteriography. A new technique. *Acta radiol* 39 (1953), 368
- VOGLER E.: Die arterio-venösen Anastomosen im Röntgenbild. *Fortschr Röntgenstr* 78 (1953), 322

caused no improvement but rather a deterioration of the peripheral contrast filling, both in patients with intact vessels and in patients with arteriosclerosis. This is surprising, since hydergine has long been used for peripheral vascular disease and is given orally, subcutaneously or intramuscularly. It has also been recommended for intraarterial use in acute peripheral arterial insufficiency, even though no objective methods of measurement have been employed in the assessment of its acute effects. The therapeutic action attributed to hydergine need not with certainty be associated with vasodilatation. The substance can intercede favourably in the cell metabolism, as demonstrated by EMMENEGER & MEIER RUGE (1968) in histochemical, circulatory and neurophysiologic studies in cats. These authors found that hydergine improved the pathologically altered brain metabolism and exerted an effect only under conditions of impaired energy formation.

Further investigations on the influence of hydergine on the cerebral blood flow have been made by GERARD et coll (1963), among others. These authors reported that hydergine administered intravenously produced a significant increase in the cerebral blood flow and increased the cerebral oxygen utilization in 18 patients, fifteen of whom had vascular lesions.

The results of the present investigations, however, do not seem to motivate the use of hydergine in acute arterial insufficiency, nor as an agent for improving peripheral arteriography. For these purposes it would appear well worth trying intraarterial administration of bradykinin both in the acute stage and over a longer period. Owing to the short decomposition time there is no general influence but only a local effect. The present author in connection with other investigations tested an infusion of bradykinin for 20 hours, no side effects were observed and the effect on the blood flow was good.

GILLESPIE (1959) discussed the use of vasodilative substances for therapeutic purposes in vascular disease and was doubtful of their value. His investigations comprised only peroral and intravenous administrations, however.

The intraarterial administration of drugs is much less common in the treatment of peripheral arterial disease. It is considered to be a complicated procedure and accompanied by risks of complications. Such administration of vasodilative drugs may, however, well be indicated in the roentgenologic examination of peripheral vessels in which the method includes the insertion of catheters.

SUMMARY

The effects of vasodilative agents on the arteriograms of twelve patients with intact blood vessels and with arteriosclerosis was investigated. Bradykinin was found to be preferable to

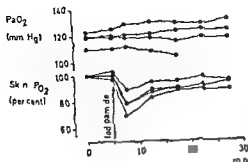


Fig. 1 Effect of an intravenous injection of Iodipamide on the oxygen tension in tissue and arterial blood (recorded simultaneously)

70 000) 6% in isotonic saline. Oxygen tension (pO_2) in tissue was recorded by polarography with a bare-tipped platinum electrode inserted intracutaneously (GROTT). The method permits continuous registration of changes in oxygen tension but not the measurement of absolute values. The oxygen tension of arterial blood was recorded with a conventional electrode. The concentration of dextran in plasma was determined according to HUNT & THORSEN.

Four cats were given an intravenous injection of 0.5 ml per kg body weight Iodipamide in 2 to 3 seconds and recordings were made of the oxygen tension in the skin and arterial blood.

Twenty-four cats, divided into three groups with 8 cats in each, received two such injections at 1 hour intervals, continuous recordings being made of the skin oxygen tension and blood pressure. Group 1 received no treatment between the injections, group 2 had an intravenous infusion of 20 ml Dextran 70 per kg body weight in the interval between the injections and group 3 had the same treatment as group 2 but with Dextran 40 instead of Dextran 70.

Results

Changes in skin oxygen tension and in arterial blood. The injection of Iodipamide induced a definite drop in the skin oxygen tension in all four animals, whereas the oxygen tension in the arterial blood remained unchanged (Fig. 1).

Changes in blood pressure and skin oxygen tension before and after treatment. The first injection of Iodipamide elicited a fall in blood pressure (mean 35%) and in the skin oxygen tension (mean 19%) in every case.

Group 1. The fall in blood pressure in these control animals was significantly smaller after the second injection of Iodipamide than after the first injection. The drop in tissue oxygen tension was also smaller after the second injection but not significantly so (see Table).

EFFECT OF DEXTRAN SOLUTIONS ON INTRAVENOUS IODIPAMIDE TOXICITY

by

C-G GROTH, B LOFSTROM and G-F SALTZMAN

Evidence has been adduced that low molecular weight dextran reduces the adverse circulatory effects of intravenously injected radiographic contrast media. This protective effect has been ascribed to the counteraction of erythrocyte aggregation or the induction of hypervolemia.

The effect of low molecular weight dextran on Iodipamide toxicity as reflected in arterial blood pressure and tissue oxygen tension was investigated in the cat. Regular dextran, which induces plasma expansion without a concomitant effect on erythrocyte aggregation, was also examined.

Material and Methods Cats weighing between 1.8 and 7 kg were anaesthetized with ether in air, tracheotomized and ventilated artificially. The depth of anaesthesia and the ventilation rate were kept constant and were the same during all the experiments. Iodipamide was administered as methylglucamine salt in a 50 % solution (Biligradin forte). The dextran solutions infused were Dextran 40 (Rheomacrodex, $M_w = 40\,000$), 10 % and Dextran 70 (Macrodex, $M_w =$

This work was supported by grants from the U.S. National Institute of Health (H 4909) and the Swedish Medical Research Council, (B67 14x 2077). Submitted for publication 5 November 1969.

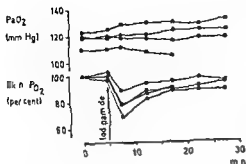


Fig 1 Effect of an intravenous injection of Iodipamide on the oxygen tension in tissue and arterial blood (recorded simultaneously)

70 000) 6% in isotonic saline. Oxygen tension (pO_2) in tissue was recorded by polarography with a bare-tipped platinum electrode inserted intracutaneously (GROTH). The method permits continuous registration of changes in oxygen tension but not the measurement of absolute values. The oxygen tension of arterial blood was recorded with a conventional electrode. The concentration of dextran in plasma was determined according to HUNT & THORSEN.

Four cats were given an intravenous injection of 0.5 ml per kg body weight Iodipamide in 2 to 3 seconds and recordings were made of the oxygen tension in the skin and arterial blood.

Twenty four cats, divided into three groups with 8 cats in each, received two such injections at 1 hour intervals, continuous recordings being made of the skin oxygen tension and blood pressure. Group 1 received no treatment between the injections, group 2 had an intravenous infusion of 20 ml Dextran 70 per kg body weight in the interval between the injections and group 3 had the same treatment as group 2 but with Dextran 40 instead of Dextran 70.

Results

Changes in skin oxygen tension and in arterial blood. The injection of Iodipamide induced a definite drop in the skin oxygen tension in all four animals, whereas the oxygen tension in the arterial blood remained unchanged (Fig 1).

Changes in blood pressure and skin oxygen tension before and after treatment. The first injection of Iodipamide elicited a fall in blood pressure (mean 35%) and in the skin oxygen tension (mean 19%) in every case.

Group 1. The fall in blood pressure in these control animals was significantly smaller after the second injection of Iodipamide than after the first injection. The drop in tissue oxygen tension was also smaller after the second injection but not significantly so (see Table).

EFFECT OF DEXTRAN SOLUTIONS ON INTRAVENOUS IODIPAMIDE TOXICITY

by

C G GROTH, B LOFSTROM and G-F SALTZMAN

Evidence has been adduced that low molecular weight dextran reduces the adverse circulatory effects of intravenously injected radiographic contrast media. This protective effect has been ascribed to the counteraction of erythrocyte aggregation or the induction of hypervolemia.

The effect of low molecular weight dextran on Iodipamide toxicity as reflected in arterial blood pressure and tissue oxygen tension was investigated in the cat. Regular dextran, which induces plasma expansion without a concomitant effect on erythrocyte aggregation, was also examined.

Material and Methods Cats weighing between 1.8 and 7 kg were anaesthetized with ether in air, tracheotomized and ventilated artificially. The depth of anaesthesia and the ventilation rate were kept constant and were the same during all the experiments. Iodipamide was administered as methylglucamine salt in a 50 % solution (Bilgrain forte). The dextran solutions infused were Dextran 40 (Rheomacrodex, $M_w = 40\,000$), 10 % and Dextran 70 (Macrodex, $M_w =$

This work was supported by grants from the U.S. National Institute of Health (H 4909) and the Swedish Medical Research Council, (B67 14x 2077). Submitted for publication 5 November 1969.

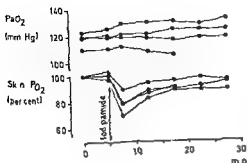


Fig 1 Effect of an intravenous injection of Iodipamide on the oxygen tension in tissue and arterial blood (recorded simultaneously)

70 000) 6 % in isotonic saline. Oxygen tension (pO_2) in tissue was recorded by polarography with a bare tipped platinum electrode inserted intracutaneously (GROTH). The method permits continuous registration of changes in oxygen tension but not the measurement of absolute values. The oxygen tension of arterial blood was recorded with a conventional electrode. The concentration of dextran in plasma was determined according to HUNT & THORSEN.

Four cats were given an intravenous injection of 0.5 ml per kg body weight Iodipamide in 2 to 3 seconds and recordings were made of the oxygen tension in the skin and arterial blood.

Twenty four cats, divided into three groups with 8 cats in each, received two such injections at 1 hour intervals, continuous recordings being made of the skin oxygen tension and blood pressure. Group 1 received no treatment between the injections, group 2 had an intravenous infusion of 20 ml Dextran 70 per kg body weight in the interval between the injections and group 3 had the same treatment as group 2 but with Dextran 40 instead of Dextran 70.

Results

Changes in skin oxygen tension and in arterial blood. The injection of Iodipamide induced a definite drop in the skin oxygen tension in all four animals, whereas the oxygen tension in the arterial blood remained unchanged (Fig 1).

Changes in blood pressure and skin oxygen tension before and after treatment. The first injection of Iodipamide elicited a fall in blood pressure (mean 35 %) and in the skin oxygen tension (mean 19 %) in every case.

Group 1. The fall in blood pressure in these control animals was significantly smaller after the second injection of Iodipamide than after the first injection. The drop in tissue oxygen tension was also smaller after the second injection but not significantly so (see Table).

Table

Percentage drop in blood pressure and skin oxygen tension at first and second injection of Iodipamide — Mean values for the groups (n = 8)

	Arterial blood pressure	Oxygen tension of skin
Controls		
First injection	37	22
Second injection	27	17
Difference \pm SE	$10 \pm 5^*$	5 ± 4
Dextran 70		
First injection	31	15
Second injection	20	10
Difference \pm SE	$11 \pm 5^*$	$5 \pm 3^{**}$
Dextran 40		
First injection	37	20
Second injection	15	7
Difference \pm SE	$22 \pm 3^*$	$13 \pm 8^{**}$

* $p < 0.001$ ** $p < 0.01$

Group 2 The second injection of Iodipamide, following an infusion of Dextran 70, again elicited a somewhat smaller drop in the blood pressure and skin oxygen tension than the first, the difference being significant in both (see Table). After the infusion of dextran the haematocrit reading had fallen from a mean of 42 % to 28 % and the mean concentration of dextran in plasma was 2.2 g %.

Group 3 The second injection of Iodipamide, following an infusion of Dextran 40, elicited a considerably smaller fall in blood pressure and tissue oxygen tension than the first injection (Fig. 2), both differences being significant (see Table). After the infusion of dextran the haematocrit reading had fallen from a mean of 41 % to 26 % and the mean concentration of dextran in plasma was 2.8 g %.

Toxic manifestations were reduced for the second injection of Iodipamide to much the same extent in groups 1 and 2, whereas group 3 displayed significantly greater reductions than group 1 in blood pressure ($p \leq 0.001$) as well as in tissue oxygen tension ($p \leq 0.05$) (Fig. 3).

Discussion

A drop in blood pressure is a familiar complication in the intravenous injection of contrast media (READ, GABER & READ, BERNSTEIN & EVANS, SALTZMAN & SUNDSTROM, LINDGREN et coll.) and the same phenomenon has been observed when other hypertonic solutions are administered (ELIAKIM et coll.,

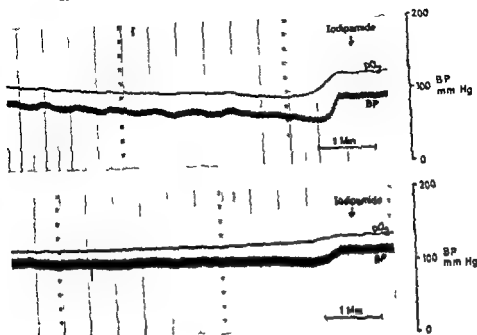
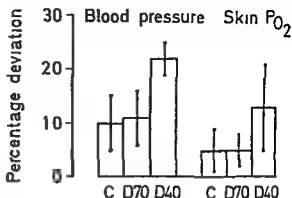


Fig 2 Typical changes in blood pressure and tissue oxygen tension on the intravenous injection of Iodipamide before (upper curve) and after (lower curve) an infusion of Dextran 40 (The curves should be read from right to left)

READ *et coll*) This effect has been ascribed to increased pulmonary resistance, resulting in reduced cardiac output and venous stasis. It has been suggested that the increased pulmonary resistance is due in turn to the hypertonic solutions inducing a crenation and aggregation of erythrocytes (SOBIV *et coll*, WIEDMAN, LINDGREN *et coll*)

It has been found that the fall in blood pressure on the injection of Iodipamide is accompanied by a reduction in peripheral blood flow (LINDGREN & SALTZMAN) Reduced blood flow seems to be the best explanation for the present finding of a drop in tissue oxygen tension since no significant change in the oxygen tension of arterial blood occurred The fact that the changes in blood pressure were always paralleled by changes in tissue oxygen tension indicates that the peripheral effect was chiefly a passive result of the pressure drop The intra arterial injection of contrast media leads to a reduction in the peripheral resistance (LINDGREN & TORVELL, LINDGREN *et coll*) and an increase in the tissue oxygen tension (HOL), probably by eliciting vasodilation, this mechanism

Fig 3 Difference in effect of the first and second injection of Iodipamide in the various groups. Mean values and standard errors



does not however appear to have any appreciable influence on conditions after the intravenous administration

Previous studies on the circulatory effects of Iodipamide injections have indicated that repeat injections have a tachyphylactic effect (LINDGREN & SALTZMAN). This phenomenon was also observed in the present investigation but, with an interval of one hour between the injections, the difference in effect was not large.

Several authors have found that low molecular weight dextran affords protection from the adverse circulatory effects of the intravenous administration of hypertonic contrast media (BERNSTEIN *et coll*, SESSIONS *et coll*, LINDGREN *et coll*). This protection has usually been attributed to favourable rheologic properties of the dextran. Results obtained by GARBER *et coll* and WIEDMAN suggested, however, that the protection more probably derived from an induced hypervolemia.

In the present experiments, judging from the changes in haematocrit readings, the two dextran solutions elicited equally large expansions of the plasma volume but only the low molecular fraction modified the circulatory effects of Iodipamide. The results therefore support the opinion that protection from the toxic effects of intravenous contrast media afforded by low molecular dextran is conveyed by a mechanism other than an increase in plasma volume. This mechanism, which has not been investigated further, could involve a counteraction by the dextran of haemorrheologic disturbances elicited by the contrast medium.

SUMMARY

The effect of low molecular weight and ordinary dextran on intravenous Iodipamide toxicity as reflected in arterial blood pressure and tissue oxygen tension was examined in the cat. Both dextran solutions induced hypervolemia but only the low molecular weight fraction had a significant protective action. It seems likely that this beneficial effect was mediated through a rheologic mechanism.

ZUSAMMENFASSUNG

Die Wirkung von Dextran mit niedrigem Molekulargewicht und von normalem Dextran auf die Toxizität von intravenös zugeführtem Iodipamide wie sie im arteriellen Blutdruck und dem Gewebs Sauerstoffdruck zum Ausdruck kommt, wurde bei der Katze geprüft. Beide Dextran-Lösungen verursachten eine Hypervolemie, aber nur die Lösung mit niedrigem Molekulargewicht hatte einen signifikanten Schutzeffekt. Es erscheint wahrscheinlich, dass der günstige Effekt über einen regulatorischen Mechanismus der Zirkulationsverhältnisse erfolgt.

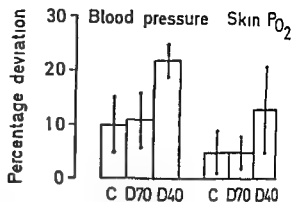
RÉSUMÉ

Les auteurs ont étudié sur le chat l'effet du dextran de faible poids moléculaire et du dextran ordinaire sur la pression artérielle et la tension en oxygène des tissus prises comme témoins de la toxicité de l'iodipamide administré par voie intra-veineuse. Ces deux solutions de dextran causent une hypervolemie, mais seule la fraction de faible poids moléculaire a un effet protecteur important. Il paraît vraisemblable que cet effet favorable est dû à un mécanisme rhéologique.

REFERENCES

- BERNSTEIN E. F. and EVANS R. L. Low molecular weight dextran. *J. Amer. med. Ass.* 174 (1960), 1417.
- — BLUM J. A. and WANT R. F. Further experimental and early clinical observations concerning the protective action of low molecular weight dextran upon Hypaque toxicity. *Radiology* 76 (1961), 260.
- ELIAKIM M., ROSENBERG S. Z. and BRAUN K. Effect of hypertonic saline on the pulmonary and systemic pressures. *Circulat. Res.* 6 (1958), 357.
- GARBER G. L. and READ R. C. Protective effect of hypervolemia in cardioangiography. *J. Amer. med. Ass.* 180 (1962), 376.
- GROTH C. G. The effect of infused plasma expander and blood on tissue oxygen tension. *Acta chir. scand.* 132 (1966), 223.
- HINT H. C. and THORSÉN G. A micro method for determination of dextran in blood. *Acta chem. scand.* 1 (1947), 808.
- HOL R. Tissue oxygen changes following contrast media injections. *Acta radiol.* 53 (1960), 266.
- LJUNGBERG P. and SALTZMAN G. F. Effects of intravenous administration of urographic and cholegraphic contrast media on blood pressure and peripheral circulation. An experimental study in cats. *Acta radiol.* 57 (1962), 341.
- and TORNELL G. Blood circulation during and after peripheral arteriography. Experimental study of the effects of Triurol (sodium acetrizoate) and Hypaque (sodium diatrizoate). *Acta radiol.* 49 (1958), 425.
- LÖFSTRÖM B. and SALTZMAN G. F. Intravascular erythrocyte aggregation after intravenous injection of contrast media. *Acta radiol. Diagnosis* 2 (1964), 334.
- SALTZMAN G. F. and TORNELL G. Vascular reaction to water soluble contrast media. Significance of concentration and total amount of iodine. *Acta radiol. Diagnosis* 7 (1968), 152.
- READ R. C. Cause of death in cardioangiography. *J. Thorac. Surg.* 38 (1959), 685.

errors



does not however appear to have any appreciable influence on conditions after the intravenous administration

Previous studies on the circulatory effects of Iodipamide injections have indicated that repeat injections have a tachyphylactic effect (LINDGREN & SALTZMAN) This phenomenon was also observed in the present investigation but, with an interval of one hour between the injections, the difference in effect was not large

Several authors have found that low molecular weight dextran affords protection from the adverse circulatory effects of the intravenous administration of hypertonic contrast media (BERNSTEIN et coll, SESSIONS et coll, LINDGREN et coll) This protection has usually been attributed to favourable rheologic properties of the dextran Results obtained by GARBER et coll and WIEDMAN suggested, however, that the protection more probably derived from an induced hypervolemia

In the present experiments, judging from the changes in haematocrit readings, the two dextran solutions elicited equally large expansions of the plasma volume but only the low molecular fraction modified the circulatory effects of Iodipamide The results therefore support the opinion that protection from the toxic effects of intravenous contrast media afforded by low molecular dextran is conveyed by a mechanism other than an increase in plasma volume This mechanism, which has not been investigated further, could involve a counteraction by the dextran of haemorrhheologic disturbances elicited by the contrast medium

SUMMARY

The effect of low molecular weight and ordinary dextran on intravenous Iodipamide toxicity as reflected in arterial blood pressure and tissue oxygen tension was examined in the cat Both dextran solutions induced hypervolemia but only the low molecular weight fraction had a significant protective action It seems likely that this beneficial effect was mediated through a rheologic mechanism

EXPERIMENTAL LYMPHOGRAPHY IN CARDIAC ARREST, ELECTRICAL VENTRICULAR FIBRILLATION AND DEEP HYPOTHERMIA

by

A CELIS, M A MENA and H DEL CASTILLO

The normal lymphographic and lymphatic flow patterns have been studied in canine hearts under normal conditions. Experimental myocardial infarction as well as trials in human subjects have proved the procedure to be innocuous (CELIS et coll 1966, 1967, 1968, 1969).

It is sometimes necessary in modern cardiac surgery to decrease or interrupt cardiac flow by modifying or temporarily abolishing cardiac contraction; this can be obtained by complete cardiac arrest, electrical ventricular fibrillation or bradycardia with hypothermia. Spontaneous cardiac arrest is clinically a fairly frequent occurrence, and occasionally effective cardiac contraction is resumed. With the advent of cardiac transplantation of hearts with spontaneous arrest, which due to technical problems are subject to variable episodes of total ischemia, the need for careful evaluation of myocardial alterations during and after these natural or technically induced conditions is most urgent (BOLOSKI et coll 1968, COX et coll 1959, HURNAGEL et coll 1961, LAWRENCE et coll 1965, POULIAS et coll 1965, STONEY et coll 1964, WALDHALSEY et coll 1960, WILLIAMS et coll 1959).

As regards the lymphatic system, only increased thoracic duct flow has been demonstrated during extracorporeal circulation (BALE et coll 1965). The state

Submitted for publication 5 December 1969

- JOHNSON J A, VICK J A and MEYER M W Vascular effects of hypertonic solutions
Circulat Res 8 (1960), 538
- SALTZMAN G F and SUNDSTROM K A The influence of different contrast media for chole-
graphy on blood pressure and pulse rate Acta radiol 54 (1960) 353
- SESSIONS R T, HILLEN D A and FOSTER J H Low molecular weight dextran as a protec-
tive agent against the toxic effects of Urokon Amer J Surg 28 (1962), 455
- SODIN S S, FRASHER W G, JACOBSON G and VAN ECKEHOVEN F A Nature of adverse
reactions to radiopaque agents, preliminary report J Amer med Ass 170 (1959) 1546
- WIEDMAN M P Influence of low molecular weight dextran on vascular and intravascular
responses to contrast media Amer J Roentgenol 92 (1964), 682



Fig 4 a) Lymphatic morphology and normal flow pattern adequate myocardial contraction in the perfused heart the myocardial and mediastinal collectors are visible b) Normal myocardial lymphatic system industrial film was used

of the myocardial lymphatics during and after arrest or ventricular fibrillation is unknown. This lack of knowledge in cardiac pathophysiology suggested our investigation of the possibilities of absorption and drainage of contrast media in the myocardial interstitial space during and after cardiac arrest, electrical ventricular fibrillation and bradycardia, in an attempt to correlate coronary perfusion and lymphatic flow rate in a heart resected for transplantation.

Material and Method The experiments were performed with the Heyman technique (Figs 1, 2 and 3). Cardiac arrest was obtained by means of potassium citrate solution 0.25% with cross clamping of the aorta or with intermittent episodes of ischemia (three times one minute). Ventricular fibrillation was produced by electric shock and deep hypothermia (Fig 2). By an arrangement similar to the one described by Lagendorf, the changes in lymphatic circulation

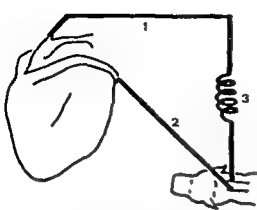


Fig 1 Innominate artery (1) and pulmonary artery (2) of the recipient dog joined to the carotid artery and jugular vein of the donor dog. The blood to the isolated heart passes through a coil (3) maintained at a constant 40°C in water.

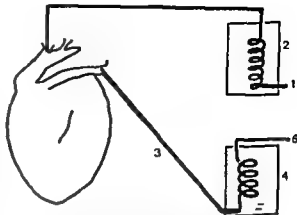
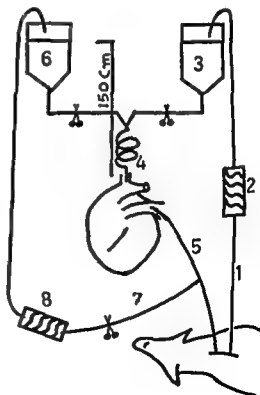
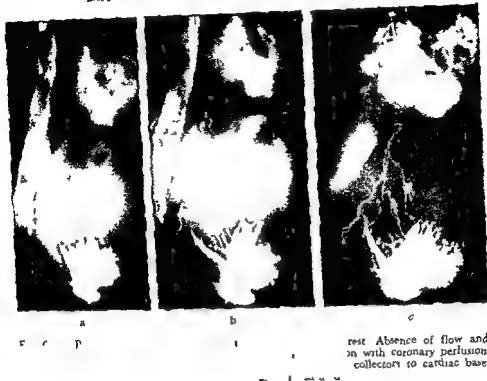


Fig 2 The blood to the perfused heart (1) cooled (15 to 18°C) by being passed through a coil immersed in water (2), the blood returning to the donor dog (3) being reheated while passing through a coil (4) submerged in hot water, maintained at 40°C .

Fig 3 The perfusing dog blood (1) is raised by a Sigmamotor pump (2) to a reservoir (3) 135 cm above the perfused heart. The blood maintained at a temperature of 38°C (4) passes to the innominate artery of the resected heart. Venous blood from the pulmonary artery going to the jugular vein of the donor animal (5). Blood with potassium citrate solution 0.25% contained in a second reservoir (6) produces complete arrest. Potassium blood may thus be changed for normal blood as required. A bypass (7) and Sigmamotor pump (8) returns the potassium blood to the reservoir (6) and prevents its passage to the donor dog.





Results

The absorption of contrast medium in the interstitial space with lymph drainage and flow identical to the normal pattern reported previously is shown for the control cases in Fig 4

In condition (2), the contrast medium was observed in the interstitial space, i.e. the coronary veins and sinus were rendered visible, in other words, a coronary phlebogram was obtained, due apparently to blockage of the contrast medium at the terminal lymphatics (Fig 5, a and b) Under the conditions indicated in (2b) as perfusion with normal blood is resumed, the contrast medium rapidly disappears from the venous system and appears in the lymphatics with normal morphologic and dynamic characteristics (Fig 5c) The drainage of the interstitial space by the lymphatics is resumed with myocardial contraction

In cardiac arrest or ventricular fibrillation due to intermittent ischemia, i.e. conditions in (3), poor absorption or drainage of the contrast medium occurred (Fig 6a) but it was overcome with re-establishment of the coronary circulation and effective myocardial contraction (Fig 6, b and c)



Fig 5 a) Complete coronary phlebogram by absorption and drainage through venous capillaries. No absorption by lymphatics in heart with total ischemia due to potassium induced arrest. b) Venous drainage of contrast medium to the coronary sinus. Total ischemia due to potassium induced arrest. c) Normal lymphatic drainage and flow in heart recuperated by coronary perfusion, same case as in (b), industrial film was used.

during potassium induced arrest with maintained coronary perfusion were studied (Fig 3).

Lymphography, in the manner described in a former work (CÉLIS et coll 1966), was carried out with serial radiography in twenty-nine resected hearts using conventional and industrial film. The method employed permitted a study of the cardiac lymphatic system under the following experimental conditions:

- 1 Lymphography in resected and perfused active hearts. 4 experiments.
- 2 Lymphographic changes during potassium-induced arrest without coronary perfusion (a), and after coronary flushing with normal blood (b). 8 experiments.
- 3 Lymphographic patterns during cardiac arrest or ventricular fibrillation induced by intermittent ischemia, and during resumption of perfusion and effective myocardial contraction. 2 experiments.
- 4 Lymphographic changes during electrically induced ventricular fibrillation with coronary perfusion and during recovery to sinus rhythm. 7 experiments.
- 5 Lymphography during severe bradycardia (8 per minute) with deep hypothermia (15 to 18° C), maintaining coronary perfusion with an extracardiac system and return to sinus rhythm and normothermia. 3 experiments.
- 6 Lymphography during potassium induced arrest, maintaining coronary perfusion with an extracardiac system (Langendorff preparation). 5 experiments.

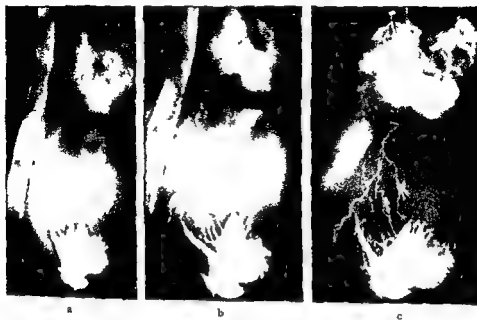


Fig 6

rest Absence of flow and
n with coronary perfusion
collectors to cardiac base

Results

The absorption of contrast medium in the interstitial space with lymph drainage and flow identical to the normal pattern reported previously is shown for the control cases in Fig 4

In condition (2), the contrast medium was observed in the interstitial space, i.e. the coronary veins and sinus were rendered visible, in other words, a coronary phlebogram was obtained, due apparently to blockage of the contrast medium at the terminal lymphatics (Fig 5, a and b) Under the conditions indicated in (2b) as perfusion with normal blood was resumed, the contrast medium rapidly disappears from the venous system and appears in the lymphatics with normal morphologic and dynamic characteristics (Fig 5c) The drainage of the interstitial space by the lymphatics is resumed with myocardial contraction

In cardiac arrest or ventricular fibrillation due to intermittent ischemia, i.e. conditions in (3), poor absorption or drainage of the contrast medium occurred (Fig 6a) but it was overcome with re-instatement of the coronary circulation and effective myocardial contraction (Fig 6, b and c)



Fig 7 a) Interstitial space and lymphatic flow through myocardial collectors to base of heart in electrical ventricular fibrillation and coronary perfusion b) Same case as in (a) Interstitial lymph flow through lateral collectors cardiac nodes and mediastinal collectors demonstrated by the use of industrial film c) Roentgenogram obtained 8 minutes after injection of contrast medium and lymph flow in heart perfused with 18° blood. Marked bradycardia. Compare this with fig 8a

In electrical ventricular fibrillation with maintained coronary perfusion, conditions in (4), the morphology and flow of the lymphatic system were normal (Fig 7, a and b)

In bradycardia with hypothermia and with maintained coronary perfusion by an extracardiac system, conditions in (5), the morphology of the lymphatics was in accord with normal appearances (Figs 7c and 8a). The flow is slow and becomes re activated with warming of the blood to normal temperature and a return to normal cardiac rate.

In cardiac arrest with potassium and with maintained extracardiac perfusion, conditions in (6), the absorption, drainage and flow of the contrast medium were normal (Fig 8b)

Discussion

The relationship between coronary perfusion or myocardial ischemia and the absorption and drainage of contrast media injected into the connective tissue were carefully considered in the investigation. The anatomical and functional



Fig 8 a) Same case as in fig 7c. Interstitial space and lymph flow to mediastinal collectors, industrial film was used b) Langendorff arrangement potassium induced cardiac arrest coronary perfusion with extracorporeal circulation. Absorption of contrast medium by the lymphatic system

state of the lymphatic system of the resected heart that had recuperated with coronary perfusion, after repeated episodes of ischemia, was also studied

It was assumed that absorption and drainage of a contrast medium by the cardiac lymphatics primarily depends on adequate coronary perfusion and secondarily on myocardial contraction. This hypothesis was supported by the following facts

With adequate coronary perfusion during potassium induced arrest, electrical ventricular fibrillation and bradycardia due to hypothermia, the absorption of the contrast medium from the interstitial space and its flow through the lymphatics could be demonstrated

Without coronary perfusion, the lymphatic terminals are apparently selectively blocked for the contrast medium, which drains through the venous system. With coronary perfusion re-established, the normal physiologic conditions of the connective tissue return, the venous capillaries are closed to the medium, and lymphatic absorption and drainage take place.

The passing of fluid and particles through the lymphatic endothelium may occur through the intercellular fissures or the vesicles of the limiting membrane. The intercellular junctions, when open, form regular channels from the surrounding intercellular spaces of the connective tissue to the lumina of the lymphatic terminals (LEAK et coll. 1968). We have found that in normal (adequate coronary perfusion and myocardial contraction) conditions, the aqueous contrast media (low molecular weight) instilled in the myocardial connective tissue, drain rapidly and selectively by the venous system and the large particles of e.g. Lipiodol Ultrafluide drain slowly through the lymphatic system. Large particles of contrast medium drain selectively through the lymphatic terminals as these have a 3 to 5 times greater diameter than the vascular capillaries (CASTLEY—SMITH 1965, 1967, PATEK 1939) and the intercellular junction, when open, is larger (LEAK et coll.). The following conditions are obtained when many of these junctions are open: flow in the collecting lymphatics with low terminal pressure, muscular contraction, variations in tissue pressure, with metabolic activity and accumulation of high molecular weight metabolites, which increases capillary filtration and produces a current that carries the large particles and opens the intercellular junctions.

It is recognized that if the lymphatic terminals permeate the Lipiodol Ultrafluide particles this must be due to the fact that many junctions are open, and that any blockage must be due to their being closed. If absorption and drainage coincide with adequate coronary perfusion, and blockage with myocardial ischemia, respectively, it must be accepted that in the first situation the junction is open and in the second instance closed.

On the basis of the previous considerations we feel that in the perfused heart, with or without myocardial contraction, the contrast medium deposited in the interstitial space becomes incorporated in the interstitial fluid formed by capillary filtration and myocardial metabolism. The fluid current would thus be established by a pressure gradient that carries the large particles (Lipiodol droplets) to the lymphatic lumina, circulating through them as lymph. The lymphographic flow patterns of this current, from the coronary capillaries to the mediastinal lymphatics and their venous junction, signify the existence of blood perfusion and probably myocardial metabolism.

Blockage of the terminal lymphatics to Lipiodol particles occurs in the non-perfused heart which drains selectively through the venous system. This blockage

may possibly be explained by the absence of capillary filtration, and a pressure gradient and fluid current which fail to open the intercellular junctions. The drainage through the venous system caused by various factors is inherent in the absence of intracapillary hydrostatic pressure,

In cardiac transplantation, the resected and isolated donor heart has its lymphatics severed. It has been subjected for periods of 5 minutes to spontaneous arrest and total ischemia, and, during the time required to establish extracorporeal circulation, to repeated episodes of ischemia. The ill effects of these adverse conditions to the recuperation and viability of the transplanted organ may be attenuated by hypothermia at 26° C, perfusing the isolated heart at a rate of 300 to 400 ml per minute, implanting it in the recipient at a temperature of 30 to 32° C and anastomosing the aorta last, in order to decrease the time of ischemia (BARNARD 1967, 1968). The hearts transplanted by COOLEY et coll (1968) are provided by individuals within hours of cerebral death and are resected before spontaneous arrest; they are subjected to short, repeated episodes of ischemia that total about 45 minutes with normothermia and without artificial perfusion. Transplanting a heart under these conditions poses problems for the recovery of effective and sustained myocardial contraction; these include the viability (DEBAKEY 1968), rejection and mutual organ host tolerance of the transplanted heart.

One of the numerous difficulties presented by this procedure is the cardiac lymphatic morphology and flow. We feel that, as in these experimental cases with a perfused heart, the absorption, drainage and flow of the contrast medium in the donor heart is maintained during the handling and first hours of transplant as long as there is adequate coronary perfusion. This extrapolation would appear to be acceptable because both hearts have been resected, isolated, perfused and revitalized by coronary perfusion after transient and repeated episodes of hypothermia and ischemia.

The fate of the lymphatic system in transplanted organs is interesting and according to the literature (COOLEY et coll 1968, CHAVEZ 1967) has been studied in pulmonary reimplantation and heterotopic renal autotransplantation into the pelvis. It is stated that during the first two or three weeks the lymphatic flow is replaced by lymphectasia and probable lympho-venous communications. Lymphography in the resected and perfused hearts of the present series demonstrated absorption in the interstitial space and flow of the contrast medium to the severed mediastinal collectors during the first few hours.

SUMMARY

The morphologic, dynamic and lymph flow changes during cardiac arrest and ventricular fibrillation in the usual surgical procedures and heart transplantation in 29 resected hearts are described. Positive cardiac lymphography appears to indicate satisfactory coronary perfusion, capillary filtration and probably maintained myocardial metabolism.

ZUSAMMENFASSUNG

Die morphologischen, dynamischen und lymphologischen Flussveränderungen während Herzstillstand und Herzfibrillieren bei der gewöhnlichen Operation und der Herztransplantation in 29 Herzen werden beschrieben. Die positive Lymphographie des Herzens scheint gute Durchströmung und gute kapillare Filtrierung und wahrscheinlich einen befriedigenden Stoffwechsel des Myokards anzuzeigen.

RÉSUMÉ

Description des modifications morphologiques, dynamiques et des débits lymphatiques pendant l'arrêt cardiaque et la fibrillation ventriculaire au cours des interventions chirurgicales habituelles et au cours de la transplantation cardiaque sur 29 cœurs prélevés. Une lymphographie cardiaque positive paraît indiquer une perfusion coronaire satisfaisante, une filtration capillaire et probablement le maintien du métabolisme myocardique.

BIBLIOGRAPHY

- BARNARD C. N. What we have learned about heart transplants. *J thorac cardiovasc Surg* 56 (1968), 457.
- A human cardiac transplant: interim report of successful operation performed at Groote-Suur Hospital. *S Afr med J* 41 (1967), 1260.
- BAUE A., NUSBAUM M., ANASTADT G. and BLACKMORE W. S. The pattern of lymphatic flow during extracorporeal circulation. *J thorac cardiovasc Surg* 50 (1965), 648.
- BOLOOMI H., ROOMS J. J., VIERA C. E. et coll.: Comparison on cardiac function and pathology. *J thorac cardiovasc Surg* 56 (1968), 590.
- CASTLEY-SMITH J. R. Endothelial permeability. II. The passage of particles through the lymphatic endothelium of normal or injured ears. *Brit J exp Path* 46 (1965), 35.
- The functioning of the lymphatic system under normal and pathological conditions: its dependence on the fine structures and permeabilities of the vessels. *In* *Progress in Lymphology*, p. 348. Georg Thieme Verlag, Stuttgart 1967.
- CÉLIS A., MARQUEZ H., DEL CASTILLO H. and MIRANGOS D. Lymphatic circulation in experimental myocardial infarction. *Acta radiol Diagnosis* 7 (1968), 438.
- DEL CASTILLO H., MARQUEZ H. et coll.: Radiologic demonstration of the lymphatic circulation of the heart. *Acta radiol Diagnosis* 4 (1966), 481.
- CICERO R., RIOS G. et coll.: Cinelymphoradiography and coronary venous radiography. *Acta radiol Diagnosis* 6 (1967), 252.
- DEL CASTILLO H. et coll.: Cardiac lymphography in human subjects. *Acta radiol Diagnosis* 8 (1969), 177.

- CONN H L, WOOD J E and MORALES C S Rate of change in myocardial glycogen and lactic acid following arrest of coronary circulation *Circulat Res* 7 (1959), 721
- COOLEY D A, BLOODWELL R D, HALLMAN G L and NORA J J Transplantation of the human heart *JAMA* 205 (1968), 479
- CHÁVEZ C M Lymphatic regeneration after transplantation *In Progress in Lymphology*, # 399 Georg Thieme Verlag, Stuttgart 1967
- DEBAKEY M E Human cardiac transplantation Editorial *J thorac cardiovasc Surg* 55 (1968) 50
- HUTNAGEL CH A, CONRAD R W, SHANNON J and PITARRE R Profound cardiac hypothermia *Amer Surg* 153 (1961), 790
- LAWRENCE K, GLIMPERT J L, NEWCOMB R W et coll The effect of induced electrical fibrillation during cardiopulmonary bypass on left ventricular function *Dis Chest* 48 (1965) 598
- LEAK L V and BURKE J F Electron microscopic study of lymphatic capillaries in the removal of connective tissue fluids and particulate substance *Lymphology* 1 (1968) 39
- MALEK P, BELAN A and KOKANDRILE V Lymphatics in renal and intestinal transplantation *In Progress of Lymphology* p 401 Georg Thieme Verlag Stuttgart 1967
- PATEK P R The morphology of the lymphatics of the human heart *Amer J Anat* 64 (1939) 203
- POLLIAS G E, ESCOBAR G, BEALL A C and DEBAKEY M E A comparison of changes in left ventricular contractile force following various methods of myocardial support *Surgery* 57 (1965) 419
- STONE R J and ROE B B Ventricular induced function after induced intermittently ischemic ventricular fibrillation effect of moderate hypothermia *J thorac cardiovasc Surg* 48 (1964), 838
- WALDHAUSEN J A, BRAUNWALD S, BLOODWELL R D et coll Left ventricular function following elective cardiac arrest *J thorac cardiovasc Surg* 39 (1960), 784
- WILLIAMS V L, COOPER TH, ZAFIRACOPOLLOS P and HANLOV C R Depression of ventricular function following elective cardiac arrest with potassium citrate *Surgery* 46 (1959), 792

SUMMARY

The morphologic, dynamic and lymph flow changes during cardiac arrest and ventricular fibrillation in the usual surgical procedures and heart transplantation in 29 resected hearts are described. Positive cardiac lymphography appears to indicate satisfactory coronary perfusion, capillary filtration and probably maintained myocardial metabolism.

ZUSAMMENFASSUNG

Die morphologischen, dynamischen und lymphologischen Flussveränderungen während Herzstillstand und Herzflimmern bei der gewöhnlichen Operation und der Herztransplantation in 29 Herzen werden beschrieben. Die positive Lymphographie des Herzens scheint gute Durchströmung und gute kapillare Filtrierung und wahrscheinlich einen befriedigenden Stoffwechsel des Myokards anzuzeigen.

RÉSUMÉ

Description des modifications morphologiques, dynamiques et des débits lymphatiques pendant l'arrêt cardiaque et la fibrillation ventriculaire au cours des interventions chirurgicales habituelles et au cours de la transplantation cardiaque sur 29 cœurs prélevés. Une lymphographie cardiaque positive paraît indiquer une perfusion coronaire satisfaisante, une filtration capillaire et probablement le maintien du métabolisme myocardique.

BIBLIOGRAPHY

- BARNARD C N What we have learned about heart transplants J thorac cardiovasc Surg 56 (1968), 457
- A human cardiac transplant interim report of successful operation performed at Groote-Suur Hospital S Afr med J 41 (1967), 1260
- BALE A, NUSBAUM M, ANASTADT G and BLACMORE W S The pattern of lymphatic flow during extracorporeal circulation J thorac cardiovasc Surg 50 (1965), 648
- BOLOOKI H, ROOKS J J, VIERA C E et coll Comparison on cardiac function and pathology J thorac cardiovasc Surg 56 (1968) 590
- CASTLE-SMITH J R Endothelial permeability, II. The passage of particles through the lymphatic endothelium of normal or injured ears Brit J exp Path 46 (1965), 35
- The functioning of the lymphatic system under normal and pathological conditions its dependence on the fine structures and permeabilities of the vessels In Progress in Lymphology, p 348 Georg Thieme Verlag, Stuttgart 1967
- CÉLIS A, MARQUEZ H, DEL CASTILLO H and MIJANGOS D Lymphatic circulation in experimental myocardial infarction Acta radiol Diagnosis 7 (1968), 438
- DEL CASTILLO H, MARQUEZ H et coll Radiologic demonstration of the lymphatic circulation of the heart Acta radiol Diagnosis 4 (1966), 481
- CICERO R, RIOS G et coll Cinelymphoradiography and coronary venous radiography Acta radiol Diagnosis 6 (1967), 252
- DEL CASTILLO H et coll Cardiac lymphography in human subjects Acta radiol Diagnosis 8 (1969), 177

- CONN H L, WOOD J E and MORALES C S Rate of change in myocardial glycogen and lactic acid following arrest of coronary circulation *Circulat. Res.* 7 (1959), 721
- COOLEY D A, BLOODWELL R D, HALLMAN G L and NORA J J Transplantation of the human heart. *J A M A* 205 (1968), 479
- CHÁVEZ C M Lymphatic regeneration after transplantation *In* *Progress in Lymphology*, II 399, Georg Thieme Verlag Stuttgart 1967
- DEBAKEY M E Human cardiac transplantation Editorial *J thorac cardiovasc Surg* 55 (1968) 55
- HUFNAGEL CH A, CONRAD R W, SHANNON J and PITTARRE R Profound cardiac hypothermia *Amer Surg* 153 (1961), 790
- LAWRENCE K, GUMPERT J L, NEWCOMB R W et coll The effect of induced electrical fibrillation during cardiopulmonary bypass on left ventricular function *Dis Chest* 48 (1965) 598
- LEAK L V and BURKE J F Electron microscopic study of lymphatic capillaries in the removal of connective tissue fluids and particulate substance *Lymphology* 1 (1968), 39
- MALEK P, BELAN A. and KOMANDRLE V Lymphatics in renal and intestinal transplantation *In* *Progress of Lymphology*, p 401 Georg Thieme Verlag, Stuttgart 1967
- PATEK P R The morphology of the lymphatics of the human heart *Amer J Anat* 64 (1939) 203
- POLLIAS G E, ESCOBAR G, BEALL A C. and DEBAKEY M E. A comparison of changes in left ventricular contractile force following various methods of myocardial support *Surgery* 57 (1965) 119
- STONEV R J and ROE B B Ventricular induced function after induced intermittently ischemic ventricular fibrillation effect of moderate hypothermia *J thorac cardiovasc Surg* 48 (1964), 838
- WALDHAUSEN J A, BRAUNWALD N S, BLOODWELL R D et coll Left ventricular function following elective cardiac arrest *J thorac cardiovasc Surg* 39 (1960), 784
- WILLIAMS V I, COOPER TH, ZAFIRACOPOLLOS P and HANLOV C. R. Depression of ventricular function following elective cardiac arrest with potassium citrate *Surgery* 46 (1959), 792

SUMMARY

The morphologic, dynamic and lymph flow changes during cardiac arrest and ventricular fibrillation in the usual surgical procedures and heart transplantation in 29 resected hearts are described. Positive cardiac lymphography appears to indicate satisfactory coronary perfusion, capillary filtration and probably maintained myocardial metabolism.

ZUSAMMENFASSUNG

Die morphologischen, dynamischen und lymphologischen Flussveränderungen während Herzstillstand und Herzflummern bei der gewöhnlichen Operation und der Herztransplantation in 29 Herzen werden beschrieben. Die positive Lymphographie des Herzens scheint gute Durchströmung und gute kapillare Filtrierung und wahrscheinlich einen befriedigenden Stoffwechsel des Myokards anzuzeigen.

RÉSUMÉ

Description des modifications morphologiques, dynamiques et des débits lymphatiques pendant l'arrêt cardiaque et la fibrillation ventriculaire au cours des interventions chirurgicales habituelles et au cours de la transplantation cardiaque sur 29 cœurs prélevés. Une lymphographie cardiaque positive paraît indiquer une perfusion coronaire satisfaisante, une filtration capillaire et probablement le maintien du métabolisme myocardique.

BIBLIOGRAPHY

- BARNARD C N What we have learned about heart transplants *J thorac cardiovasc Surg* 56 (1968), 457
- A human cardiac transplant: interim report of successful operation performed at Groote-Suur Hospital *S Afr med J* 41 (1967), 1260
- BAUE A, NUSBAUM M, ANASTADT G and BLACKMORE W S The pattern of lymphatic flow during extracorporeal circulation *J thorac cardiovasc Surg* 50 (1965), 648
- BOLOOKI H, ROOKS J J, VILRA C E et coll Comparison on cardiac function and pathology *J thorac cardiovasc Surg* 56 (1968), 590
- CASTLEY-SMITH J R Endothelial permeability II The passage of particles through the lymphatic endothelium of normal or injured ears *Brit J exp Path* 46 (1965), 35
- The functioning of the lymphatic system under normal and pathological conditions its dependence on the fine structures and permeabilities of the vessels *In Progress in Lymphology*, p 348 Georg Thieme Verlag, Stuttgart 1967
- CÉLIS A, MARQUEZ H, DEL CASTILLO H and MIJANGOS D Lymphatic circulation in experimental myocardial infarction *Acta radiol Diagnosis* 7 (1968), 438
- DEL CASTILLO H, MARQUEZ H et coll Radiologic demonstration of the lymphatic circulation of the heart *Acta radiol Diagnosis* 4 (1966), 481
- CIGERO R, RIOS G et coll Cinelymphoradiography and coronary venous radiography *Acta radiol Diagnosis* 6 (1967), 252
- DEL CASTILLO H et coll Cardiac lymphography in human subjects *Acta radiol Diagnosis* 8 (1969), 177



Fig 1 Arterial phase in normal angiography of a renal allograft 24 hours following transplantation

changes of rejection. The primary renal disease had been chronic glomerulonephritis in fourteen patients, chronic pyelonephritis in two and polycystic kidneys in two patients. All but one graft were obtained from non living donors. The transplants were anastomosed to the iliac vessels, generally the renal artery end to end with the internal iliac artery and the vein end to side with the common iliac vein. Immunosuppressive therapy consisted of prednisone or its analogues and azathioprine, actinomycin C was used in a few patients. Earlier patients were also treated with graft irradiation.

Examination methods The percutaneous technique with a Kifa red or thin-walled red catheter was used. Generally the contralateral femoral artery was punctured and the tip of the catheter placed in the ipsilateral common iliac artery as near as possible to the origin of the internal iliac artery. Selective injection of

FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR PROF OLLE OLSSON)
THE UNIVERSITY HOSPITAL, LUND, SWEDEN, AND THE DEPARTMENTS OF RADIOLOGY
(DIRECTOR PROF CLYDE M WILLIAMS), SURGERY (DIRECTOR PROF EDWARD R
WOODWARD) AND PATHOLOGY (DIRECTOR PROF RICHARD T SMITH), UNIVERSITY
OF FLORIDA COLLEGE OF MEDICINE, GAINESVILLE, FLORIDA, U S A

ANGIOGRAPHIC DIAGNOSIS OF REJECTION AND TUBULAR NECROSIS IN HUMAN KIDNEY ALLOGRAFTS

by

J KAUDE, D H SLUSHER, W W PFAFF and R L HACKETT

Oliguria or anuria is not an infrequent complication of renal transplantation of cadaveric kidneys (CALNE et coll 1963), the most common causes being immunologic rejection or ischemic tubular necrosis. Differentiation between these disparate states may be difficult on clinical grounds alone but can usually be accomplished by percutaneous biopsy (KINCAID SMITH 1967). Not infrequently, however, the biopsy material may be insufficient to allow definite conclusions or may result in residual vascular abnormalities (SWEET et coll 1969, EKELOUND 1970) and untoward effects in a critically ill patient. When these limitations became apparent angiography was employed to aid in the diagnosis of these and other causes of functional failure of a renal graft.

Material Twenty nine angiographic examinations (19 in Gainesville and 10 in Lund) were performed in eighteen patients: first and second grafts were examined in four patients. The principal indication for angiography was oliguria or anuria. One patient was investigated to evaluate the etiology of persistent hypertension, and two examinations were made to determine the resolution of earlier

Submitted for publication 16 December 1969



Fig 4 Cortical necrosis secondary to necrotizing vasculitis examination performed 24 days following transplantation a) kidney not enlarged marked truncation of the interlobar arteries secondary to peripheral obstruction b) Circulation time markedly prolonged the contrast medium remaining in the kidney at 12 seconds following injection indicates presence of renal vein thrombosis

needle biopsies. The latter were generally obtained within 4 days of the radiographic procedure. The kidney was removed the day following angiography in one patient and open biopsy was performed in three patients. Major vessel thrombosis complicating completed rejection was confirmed by graft nephrectomy. Biopsies were not performed in three patients. angiographic findings.

Results and Discussion

Only one angiographic examination was normal (Fig 1). Acute rejection was demonstrated in ten examinations and chronic or healed rejection was noted in four. Rejection vasculitis had caused obstruction of the interlobar arteries



Fig 2 Acute rejection 51 days following transplantation. Kidney edematous, arteries stretched and peripheral vessels unfilled, irregularities in the arterial lumen are localized in the pars intermedia. The arterial emptying time was 6 seconds. Light microscopy showed severe rejection, with necrotizing vasculitis.



Fig 3 Acute rejection with severe vasculitis but without marked renal edema. Examination performed 7 days following transplantation and 2 days after marked decline in function. The arterial emptying time was 3 seconds. Renal veins not demonstrated, faint nephrographic phase.

the internal iliac artery was performed in three instances, 10 to 15 ml of Renografin 60 % or Isopaque Cerebral were injected by hand. In common iliac injections, 12 to 30 ml were used, the volume varying with the size of the artery and the age of the patient.

The films were exposed in an Elema-Schonander 14" \times 14" cut film changer, the film rate being 2 per second for 3 seconds, 1 per second for 3 seconds, and an additional 3 films in 6 or 9 seconds. A late exposure was obtained to determine the presence or absence of excretion of contrast medium by the graft. In one patient, retrograde pyelography was performed immediately following angiography, and in some instances 70-mm serial fluorography at a rate of 3 films per second was performed for a more accurate estimation of the renal circulation time. The focal spot was 0.6 or 1.2 mm. No complications from the procedure were observed.

Angiographic findings were compared with histologic diagnoses of percutaneous



n & dnev
for those
on time

thrombosis ultimately leading to obliteration. Medial necrosis is a

As the site of rejection is the vessels, angiography is a particularly apt diagnostic method of demonstrating the reaction. In earlier investigations angiographic findings in rejection of human renal transplants have included edema, prolongation of the arterial circulation time, irregularities and obliteration



Fig 5 Chronic or healed rejection angiogram 10 months following transplantation. Kidney of normal size, narrowing of interlobar arteries and reduced number of peripheral cortical arteries as well as medullary branches. The arterial emptying time was 2.7 seconds. Kidney functioning although at half the maximal initial function.

resulting in uniform cortical necrosis associated with renal vein thrombosis in two examinations. In one examination, cortical necrosis resulted from ischemia due to renal artery obstruction of several hours duration. Signs of both acute and chronic rejection were noted in one patient.

Anuria in four patients appeared to be the consequence of ischemic acute tubular necrosis, although it was eventually associated with focal rejection. Thrombosis of the arterial anastomosis was revealed in two examinations. The anastomosis was stenotic in two grafts and in one patient narrowing with poststenotic dilatation was noted at the origin of the internal iliac artery. A blood clot obstructed the ureteropelvic junction in one patient; this was confirmed by pyelography.

There was uniform correlation of the angiographic diagnosis with either histologic data or clinical conclusions as evidenced by the end results.

Convincing evidence has been presented that the primary site of immunologic rejection of renal transplants is the vascular endothelium (Kouyatz et coll 1963, Knudsen et coll 1967). Rejection vasculitis has been characterized by subintimal round cell infiltration and fibrin deposits resulting in mural



FIG. 3. a) Normal contrast medium filling of the renal parenchyma. b) Non-filling character of the renal parenchyma in contrast to the normal filling character of the renal parenchyma in immunologic rejection.

immunologic rejection

are stretched by edema. Irregularities in the arterial lumen caused by subintimal and mural cellular infiltration are present. If angiography is repeated following intensification of immunosuppressive therapy, the edema of the kidney may be less marked although vascular changes may persist (Fig. 3).

The arterial circulation time is prolonged and varies with the severity of the rejection. In clear cut rejection the arterial phase varied from 2.5 to 6 seconds. In three patients with mild rejection the arterial phase was normal (1 to 2 seconds). This was determined by the interval between the appearance of the last portion of the contrast medium in the renal artery and the emptying of the peripheral arteries. This method of estimating the arterial emptying time is obviously not very accurate but with the angiographic technique employed (injection of contrast medium into the common iliac artery and a film rate

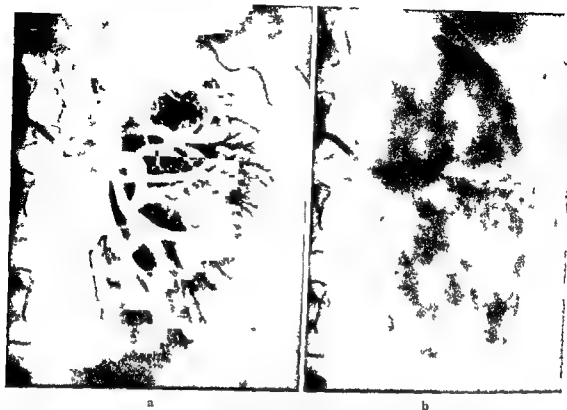


Fig 7 Angiography in acute tubular necrosis in kidney (not transplanted) examined 7 days following onset of anuria a) Normal kidney size arteries unremarkable with emptying time of 1.5 seconds b) Good nephrographic phase and filling of veins no contrast medium in the collecting system in the late films

tion of the arteries, with absence of the peripheral vasculature and a poor nephrographic phase (ALFIDI et coll 1966, O'CONNOR et coll 1967, STAPLE & CHIANG 1967, BRUCKE et coll 1968, KAUDE et coll 1969, VINIK et coll 1969). In experiments with canine renal transplants, the angiographic findings in rejection have been found to be essentially similar to those in clinical work in man (DEMPSTER 1955, KNUDSEN et coll 1967).

Angiographic findings in tubular necrosis caused by prolonged renal ischemia before or during grafting have been reported in only one patient and were histologically unverified (BRUCKE et coll 1968).

The angiographic findings in rejection in our material are in agreement with those reported by ALFIDI et coll, O'CONNOR et coll, STAPLE & CHIANG and BRUCKE et coll. We also agree with VINIK et coll in their statement that it is possible to differentiate angiographically between acute and chronic stages of rejection. In acute rejection (Fig 2), the kidney is enlarged and the arteries

veins may sometimes be present in such cases and, depending on the current state of the renal function, contrast medium may be excreted.

The circulation time in ischemic acute tubular necrosis (Fig 6) was normal or only slightly prolonged and, with one reservation, varied from 1 to 2 seconds. In one examination, the arterial emptying time was 3 seconds, this was attributed to the presence of admixed immunologic rejection. In three patients

biopsy (Fig 6a). No other arterial changes were noted, the distal and small peripheral vessels were filled with contrast medium. A nephrographic effect was invariably present, although the borderline between the cortex and medulla could be hard to define. The renal veins were filled in late films. Presumably, as a result of the absence of kidney function, an increased concentration of the contrast medium in the veins was usually observed (Fig 6b).

In a patient with ischemic necrosis in a non-transplanted kidney (Fig 7) in whom clinical and histologic verification was consistent with the diagnosis of ischemic acute tubular necrosis. The arteries and arterial emptying time were normal, the renal veins were filled with contrast medium and nephrographic effect was present although no contrast medium was excreted.

A similar identification of the renal veins was noted in a patient with cortical necrosis following renal artery obstruction of several hours duration. Peripheral arterial lesions were also observed in this case (Fig 8). The latter findings were similar to those described in experimental investigations and believed to be caused mainly by renal arterial spasm (SHERWOOD et coll 1969).

Further complications following kidney transplantation, to be differentiated from acute rejection and ischemic tubular necrosis, are renal vein thrombosis and renal failure secondary to urinary obstruction. In renal vein thrombosis, the blood flow in the kidney is retarded (CRUMM & HIRONA 1965, KOEHLER et coll 1966, ALFIDI et coll 1966) but if not associated with or not secondary to rejection no vasculitis is present. The diagnosis of renal vein thrombosis may be verified by renal phlebography (ALFIDI et coll). In a patient with urinary obstruction (Fig 9, a and b), the renal vasculature was normal but a marked nephrographic effect persisted for more than 18 seconds. Pyelography performed immediately following angiography revealed a blood clot at the ureteropelvic junction as the cause of the renal stasis (Fig 9c).

Local vascular irregularities as the result of focal rejection need to be differentiated from changes that may follow needle biopsy (SWEET et coll 1969). Percutaneous needle biopsy was performed prior to angiography in five of our

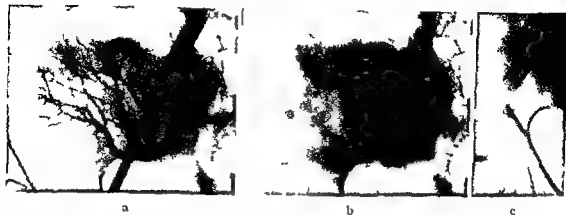


Fig 9 Kidney failure secondary to urinary obstruction 5 day old transplant a) Normal arteriography No vasculitis or renal edema the arterial emptying time was 15 seconds b) Marked nephrographic phase persisting for more than 18 seconds c) Pyelography revealed a blood clot at the ureteropelvic junction as the cause of the renal stasis

of 2 to 3 films per second) its application is warranted from a practical point of view and permits a determination of the arterial emptying time within the acceptable range of error, approximately 0.3 to 0.5 seconds.

Additional radiographic findings depended upon the intensity of rejection, the stage at which the examination was performed, the character of the immunosuppressive therapy and the response to this treatment. In acute rejection, either no filling with contrast medium of the interlobar peripheral branches and the arcuate and interlobular arteries took place or the filling was incomplete (Figs 2 and 3). The nephrographic phase was poor or absent. Reduced capillary flow prevented demonstration of the veins. Little or none of the contrast medium was excreted by the kidneys.

With progressive rejection, the peripheral branches of the interlobar arteries, including branches descending into the medulla (KNUDSEN *et al.* 1967), as well as the primary interlobar vessels themselves, became obliterated, with resultant cortical necrosis (Fig 4).

Response to immunosuppressive therapy may result in conversion of the angiographic findings of acute rejection to those of healed or chronic rejection, as illustrated in Fig 5. The kidney size in this instance was decreased and the caliber of the renal arteries was reduced, although the lumina remained irregular. When correlated with the microscopic findings, this appeared partly to be due to organized subintimal infiltration and interstitial fibrosis. The number of interlobar arteries was reduced, presumably because of obliteration of vessels as a result of the acute rejection. The circulation time was normal or slightly prolonged and ranged from 1.5 to 2.5 seconds. Faint contrast filling of the

veins may sometimes be present in such cases and, depending on the current state of the renal function, contrast medium may be excreted.

The circulation time in ischemic acute tubular necrosis (Fig 6) was normal or only slightly prolonged and, with one reservation, varied from 1 to 2 seconds. In one examination, the arterial emptying time was 3 seconds, this was attributed to the presence of admixed immunologic rejection. In three patients

biopsy (Fig 6a) No other arterial changes were noted, the arcuate arteries and small peripheral vessels were filled with contrast medium. A nephrographic effect was invariably present, although the borderline between the cortex and medulla could be hard to define. The renal veins were filled in late films. Presumably, as a result of the absence of kidney function, an increased concentration of the contrast medium in the veins was usually observed (Fig 6b).

Further verification of the angiographic findings of acute tubular necrosis in transplanted kidneys was provided by an opportunity to examine a patient with a non transplanted kidney (Fig 7) in whom clinical and histologic verification was consistent with the diagnosis of ischemic acute tubular necrosis. The arteries and arterial emptying time were normal, the renal veins were filled with contrast medium and nephrographic effect was present although no contrast medium was excreted.

A similar identification of the renal veins was noted in a patient with cortical necrosis following renal artery obstruction of several hours duration. Peripheral arterial lesions were also observed in this case (Fig 8). The latter findings were similar to those described in experimental investigations and believed to be caused mainly by renal arterial spasm (SHERWOOD et coll 1969).

Further complications following kidney transplantation, to be differentiated from acute rejection and ischemic tubular necrosis, are renal vein thrombosis and renal failure secondary to urinary obstruction. In renal vein thrombosis, the blood flow in the kidney is retarded (CRUMM & HIPONA 1965, KOEHLER et coll 1966, ALFIDI et coll 1966) but if not associated with or not secondary to rejection no vasculitis is present. The diagnosis of renal vein thrombosis may be verified by renal phlebography (ALFIDI et coll). In a patient with urinary obstruction (Fig 9, a and b), the renal vasculature was normal but a marked nephrographic effect persisted for more than 18 seconds. Pyelography performed immediately following angiography revealed a blood clot at the ureteropelvic junction as the cause of the renal stasis (Fig 9c).

jection need to be differentiated (SWEET et coll 1969). Pyelography in five of our

patients In two of these, residual vascular irregularities but no resultant arteriovenous fistulas were observed (Fig 6a)

A summary of the angiographic findings in acute rejection and tubular necrosis is given in the following

	<i>Acute rejection</i>	<i>Tubular necrosis</i>
Kidney size	Enlarged	Normal or slightly enlarged
Edema	Present	Absent or mild
Circulation time	Prolonged (normal in mild rejection)	Normal or slightly prolonged
Vasculitis	Present	Absent
Nephrogram	Poor or absent	Present
Renal veins	Not filled	Filled
Contrast excretion	Absent	Absent

A particularly careful technique is essential in the investigation of renal transplants in order to be able to evaluate changes in small vessels Only with injection into the internal or ipsilateral common iliac arteries have we been able to obtain films of good diagnostic quality For selective techniques the introduction of a catheter into the internal iliac artery is usually preferred The anastomosis generally lies 3 to 5 cm distally from the origin of the vessel and although sub intimal injection is a potential complication it should rarely occur However antegrade semi selective injection into the common iliac artery following puncture of the contralateral femoral artery is equally successful and necessitates only a small increase in the amount of contrast medium employed It has the additional advantage of allowing more adequate evaluation of the proximal internal iliac artery A high incidence of atherosclerotic lesions occur in uremic patients even in young individuals Significant calcification of the internal iliac artery was noted on two occasions in our series and in one patient there was marked stenosis at the origin of the internal iliac artery with significant post stenotic dilatation

Further technical refinement may be achieved with a 0.3 mm focal spot and geometric magnification (TAKARO 1967 BAUM et coll 1968) This has been particularly useful in evaluating the peripheral vasculature of the kidney (TAKARO 1967 SHERWOOD et coll 1969 LAVENDER et coll 1969 OLIN & SAKUMA 1969) and may prove to be an important aid in the detection of small vessel vasculitis Clarification of peripheral lesions may also be aided by subtraction techniques

SUMMARY

Angiography was performed on 29 occasions following 22 renal allografts in 18 human subjects and proved to be an aid in the differential diagnosis between immunologic rejection and ischemic acute tubular necrosis. The angiographic findings in the various stages of rejection in the presence of tubular necrosis and in other complications following transplantation are described. These were found to correlate with the microscopic and clinical diagnoses. The technique of angiography in renal transplants is discussed.

ZUSAMMENFASSUNG

Nierenangiographie wurde in 29 Fällen vorgenommen und erwies sich als eine wertvolle diagnostisch zwischen Abstoßungsreaktion und akuter tubulärer Nekrose zu unterscheiden. Die angiographischen Befunde während den verschiedenen Stadien der Abstoßungsreaktion beim Vorliegen einer tubulären Nekrose und bei anderen Komplikationen nach Nierentransplantation werden beschrieben. Die angiographischen Befunde stimmten in sämtlichen Fällen mit der histologischen Diagnose und dem klinischen Verlauf überein. Die Technik der Angiographie der transplantierten Niere wird besprochen.

RÉSUMÉ

Les auteurs ont pratiqué 29 angiographies après 22 allotransplantations rénales chez 18 malades; cet examen s'est montré utile pour le diagnostic différentiel entre le rejet immunologique et la nécrose tubulaire ischémique aiguë. Les auteurs décrivent les signes angiographiques aux différents stades du rejet dans le cas de nécrose tubulaire et dans les autres complications qui survient la transplantation. Les signes angiographiques sont en concordance avec les diagnostics microscopiques et cliniques. Les auteurs étudient la technique de l'angiographie dans les transplantations rénales.

REFERENCES

- ALFRED R. J. MEANEY TH. F. BLOKOCORE E. and YAMAMOTO S. Evaluation of renal homotransplantation by selective angiography. *Radiology* 87 (1966) 1099.
- BALM S. ALRODA K. MISHKIN M. et coll. Direct serial magnification techniques in abdominal and cerebral angiography. Paper read at 54th Scientific Assembly and Annual Meeting RSNA Chicago 1968.
- BRUCKE F. POMMER H. PIZA F. und ZALBACHER W. Angiographische Untersuchungen vor und nach Nierentransplantation. In: *Angiographie und ihre Leistungen*, S. 162. Herausg. H. E. Loose. Georg Thieme Verlag Stuttgart 1968.
- CALNE R. Y. LOUGHRIDGE L. W. MACGILLIVRAY J. B. et coll. Renal transplantation in man. A report of five cases using cadaveric donors. *Brit. med. J.* 1963 II, p. 645.
- CRUMRY A. B. and HIPPOY A. F. A. The roentgen diagnosis of renal vein thrombosis. Experimental aspects. *Amer. J. Roentgenol.* 93 (1965) 898.
- DEMPSTER W. J. A consideration of functional arrest of homotransplanted kidneys. *Brit. J. Urol.* 27 (1955) 66.

- EKELUND L: Arteriovenous fistulas secondary to renal biopsy. An experimental study in the rabbit. *Acta radiol* Diagnosis 10 (1970), 218
- KAUDE J, SLUSHER B H, PFAFF W W och HACKETT R L: Angiografi vid rektion och tubular nekros i transplanterad njure (In Swedish) Paper read at 30th Congress of the Nordic Society for Medical Radiology, Helsinki 1969
- KINCAID SMITH P: Histological diagnosis of rejection of renal homografts in man. *Lancet* 1967 II, p 849
- KNUDSEN D F, DAVIDSON A J, KOUNTZ S L and COHN R: Serial angiography in canine renal allografts. *Transplantation* 5 (1967), 256
- KOEHLER P R, BOWLES W T and McALISTER W H: Renal arteriography in experimental renal vein occlusion. *Radiology* 86 (1966), 851
- KOUNTZ S L, WILLIAMS M A, WILLIAMS P L et coll: Mechanism of rejection of homotransplanted kidneys. *Nature* 199 (1963), 257
- LAVENDER J P, SHERWOOD T and RUSSELL S: In vivo renal micro angiography: an experimental technique to study cortical perfusion during haemorrhagic shock. *Brit J Radiol* 42 (1969), 247
- O'CONNOR J F, DEALY JR J B, LINDQUIST R and COUCH N P: Arterial lesions due to rejection in human kidney allografts. *Radiology* 89 (1967), 614
- OLIN T och SAKUMA S: Glomerulografi en experimentell studie på smådjur (In Swedish) Scientific exhibition at the 30th Congress of Nordic Society for Medical Radiology, Helsinki 1969
- PORTER H A, MARCIHORO T L and STARZL T E: Pathological changes in 37 human renal homotransplants treated with immunosuppressive drugs. *Brit J Urol* 37 (1965), 250
- THOMSON W B, OWEN K et coll: Obliterative vascular changes in four human kidney homotransplants. *Brit med J* 1963 II, p 639
- DOSSETOR J B, MARCIHORO T L et coll: Human renal transplants. I. Glomerular changes. *Lab Invest* 16 (1967), 153
- SHERWOOD T, LAVENDER J P and GREENSPAN R H: Renal magnification angiograms in the dog: Observations on response to vasodilators and surgical trauma. *Brit J Radiol* 42 (1969), 241
- STAPLE T W and CHIANG D T C: Arteriography following renal transplantation. *Amer J Roentgenol* 101 (1967), 669
- SWEET E I, DAVIDSON A J and HAYSLITT J P: Complications of needle biopsy of the kidney in the dog. *Radiology* 92 (1969), 849
- TANABE T: Experimental renal glomerulography. *Amer J Roentgenol* 101 (1967), 681
- VINIK M, SMELLIE W A B, FREED T A et coll: Angiographic evaluation of the human homotransplant kidney. *Radiology* 92 (1969), 873

HYSTEROGRAPHY IN INTRAUTERINE PREGNANCY AND ABORTION

Report of three cases

by

MOGENS HONORE

HysteroGRAPHy has lost much of its significance in the diagnosis of early pregnancy with the coming of biologic pregnancy tests. The procedure has, however, still been resorted to in confirming a diagnosis of tubal pregnancy or even cervical gestation (MATRACARU et coll 1966).

HELSEK (1925) was the first to inject iodized oil into the pregnant uterus as a routine measure. MARTINEZ & MILLER (1928) reported 15 cases of pregnancy so diagnosed, three of which terminated in abortion. HysteroGRAMs of intact intrauterine pregnancy are now obtained only accidentally. KJELLBERG (1942) observed one case in a consecutive material of 328 cases of hysterosalpingopelviographies and GOLDBERGER et coll (1950) reported two cases of early pregnancy in a review of 2 500 cases. SALASC (1965) reported a case leading to a false diagnosis of uterine fibroid and put the risk of abortion following the examination at up to 10 %.

HysteroGRAPHy may still be of some value in diagnosing a condition of missed

Submitted for publication 18 November 1969



Fig 1 Case 1 Intact intrauterine pregnancy Hystero-gram, oblique anteroposterior (a) and lateral (b) views

abortion AHUMADA et coll (1956) reported 13 cases in eleven of which a correct diagnosis was apparently made. These authors stressed that hystero-gram should not be performed unless death of the embryo is certain, and that at least 10 to 15 ml of the aqueous contrast medium should be used to obtain a reasonable filling of the enlarged cavity.

The hystero-gram of early intact pregnancy generally reveals an enlarged, atonic and globular cavity with a rounded contrast defect close to the wall and a small cervical canal. In certain instances, including missed abortion, the defect may be more irregular and suggest carcinoma of the corpus, submucous and intramural fibromyoma, or endometrial polyps. The changes may be difficult to interpret and may be obscured by a combination of conditions or by infection. (The reader is referred to SCHWAZ 'Lehrbuch der Röntgendiagnostik' 1965, DALSACE et coll 1959 and ERBSLOH 1957.)

Material This consisted of 1 266 hystero-grams performed during the period 1964—1969. Three cases of intrauterine pregnancy and abortion were encountered and are now reported.

Case reports

Case 1 Woman, aged 23, was admitted to the Gynecologic Department for treatment of a palpable orange sized ovarian cyst. Following left oophorectomy the patient had had more or less continuous abdominal symptoms suggesting adnexial inflammation but on examination the cyst had apparently disappeared. No pregnancy test was performed.

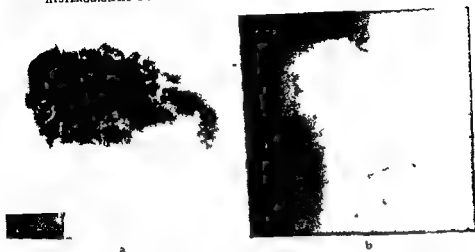


Fig 2 Case 2 Infected abortion Hystero-graphy oblique anteroposterior (a) and lateral (b) views.

Hystero-graphy revealed a considerably enlarged ante-flected uterus with an internal diameter of about 11 cm (Fig 1). The cervical canal was small. A rounded broad based smooth contrast defect approximately 8 cm in size lay at the fundus and the anterior wall. The tubes were only partly filled. The appearances were highly suggestive of pregnancy, a diagnosis confirmed clinically and by a pregnancy test. The pregnancy was terminated.



Fig 3 Case 3 Missed abortion Hystero-graphy oblique anteroposterior (a) and lateral (b) views.



Fig 1 Case 1 Intact intrauterine pregnancy Hystero-grams, oblique anteroposterior (a) and lateral (b) views

abortion AHUMADA *et coll* (1956) reported 13 cases in eleven of which a correct diagnosis was apparently made These authors stressed that hystero-grams should not be performed unless death of the embryo is certain, and that at least 10 to 15 ml of the aqueous contrast medium should be used to obtain a reasonable filling of the enlarged cavity

The hystero-gram of early intact pregnancy generally reveals an enlarged, atonic and globular cavity with a rounded contrast defect close to the wall and a small cervical canal In certain instances, including missed abortion, the defect may be more irregular and suggest carcinoma of the corpus, submucous and intramural fibromyoma, or endometrial polyps The changes may be difficult to interpret and may be obscured by a combination of conditions or by infection (The reader is referred to SCHINZ 'Lehrbuch der Röntgendiagnostik' 1965, DALSACE *et coll* 1959 and LEBSON 1957)

Material This consisted of 1 266 hystero-grams performed during the period 1964—1969 Three cases of intrauterine pregnancy and abortion were encountered and are now reported

Case reports

Case 1 A 28-year-old woman with a history of menorrhagia and less continuous abdominal symptoms suggesting adnexial inflammation but no pregnancy test was performed the cyst had apparently disappeared No pregnancy test was performed

ZUSAMMENFASSUNG

Drei Fälle von Hysterographie bei intrauteriner Gravidität und Abort werden vorgelegt und die röntgenologische Diagnose wird besprochen. Es wird betont, dass es wichtig ist, bevor der Hysterographie eine Gravidität auszuschliessen.

RÉSUMÉ

Présentation de trois cas d'hystérogaphie au cours de grossesses intrautérines et d'avortements. L'auteur discute le diagnostic et souligne l'importance de s'assurer qu'il n'y a pas une grossesse avant de faire une hystérogaphie.

REFERENCES

- ARMSTRAD J. C., VOGLES A. E. and DONOVAN C. Hystero-graphy in the diagnosis of dead and retained human ovum. *Amer J Obstet Gynec* 71 (1956), 1274.
- DALACE J. and GARCIA CALDERON J. *Gynecologic radiography*. Harper and Brothers, New York 1959.
- ERBSLOH J. Das Röntgenbild der Metrorrhagien und seine Differentialdiagnose. *Zbl Gynak* 79 (1957) 1047.
- GOLDBERGER M. A., MARSHAK R. and DAVIDS A. Hystero-graphy and hysterosalpingography. An evaluation of 2500 cases. *N Y J Med* 50 (1950), 2697.
- HELIER C. Lipiodol in the diagnosis of pregnancy. *Lancet* 209 (1925), p. 1111.
- KJELLBERG S. R. Hysterosalpingopelviographie. *Acta radiol.* (1942) Suppl. No. 43.
- MARTINEZ D. B. and MILLER H. A. Iodized oil in the diagnosis of pregnancy. *Radiology* 11 (1928) 191.
- MATRACARI G., IACOB C., CONSTANTINESCU P. et coll. Cervicohysterosalpingography in cervical pregnancy. *Amer J Obstet Gynec* 94 (1966) 929.
- SALABEC J. Hystérogaphie et grossesse normale. *Bull. Féd. Soc. Gynéc. Obstét. franç.* 17 (1965), 476.
- SCHINZ H. R., BAENSCH W. E., FROMMOLD W. et coll. *Lehrbuch der Röntgendiagnostik*. Band 5. Georg Thieme Verlag, Stuttgart 1965.

Case 2 Woman, aged 20, with a history of menorrhagia and endometritis. The patient had been bleeding irregularly for two months and treated with oestrogens and iron. The uterus had been of normal size and not tender. No pregnancy test was made.

Hystero-graphy disclosed that the uterine cavity was relatively large with a coarse and irregular mucosal pattern probably due to endometritis and myometritis. The tubes were not filled (Fig. 2).

Subsequently, the patient developed fever and pain in the lower part of the back associated with a bloody vaginal discharge. Palpation of the uterus now suggested a pregnancy of three months, small portions of placental tissue were protruding through the cervix. Evacuation of the uterus was performed. Microscopy disclosed material consisting of pus and fragments of pregnant decidua, no villi were visible and there was no evidence of a mole or of malignant proliferation. The diagnosis was abortion and endometritis.

Case 3 Woman, aged 32, was admitted with probable abortion in the 4—5 months of pregnancy. Two pregnancy tests were negative. The uterus was enlarged and a fibroid lay at the fundus.

Hystero-graphy disclosed an enlarged globular cavity with a rounded, partly irregular contrast defect close to the wall (Fig. 3). The cervix was relatively narrow with no sharp demarcation of the internal orifice. The appearances corresponded well to the clinical diagnosis of missed abortion. Microscopy after evacuation revealed products of abortion.

An aqueous contrast medium consisting of 200 mg iodine/ml was employed in these cases.

Discussion

Abdominal roentgen exposures on women of fertile age are withheld as a routine particularly within the first half of pregnancy. Cases of pregnancy will of course appear at intervals and give rise to various problems. A pregnancy test would have given the clue in Case 1, and an extensive use of pregnancy tests before hystero-graphy appears most desirable. The hystero-gram in Case 2 indicated a condition of abortion and infection, the administration of oestrogen over a period may possibly have influenced the picture. But for the patient's age the possibility of a villous carcinoma of the corpus might have been considered. Case 3 was somewhat typical of missed abortion and hystero-graphy combined with negative pregnancy tests and clinical evidence afforded valuable diagnostic support.

SUMMARY

Three cases of hystero-graphy in connection with intrauterine pregnancy and abortion are presented and the diagnosis is discussed. The importance of excluding pregnancy before hystero-graphy is stressed.

Two pulsating subcutaneous arteries proved to be too small for arteriography. A polythene No 160 catheter was introduced into the draining vein and the contrast medium injected in a retrograde direction (Gidlund produced in Fig 1b c and d). Numerical whole mass was richly vascularized.

The long history and the findings suggested a cystosarcoma phyllodes and the phlebographic appearances consistent with a benign tumour appeared to confirm the diagnosis. The tumour was excised locally without difficulty and proved to be a benign cystosarcoma phyllodes. No local recurrence and no metastases have occurred five years after the operation.

Case 2 Woman, aged 42, adipose, had 4 weeks prior to admission noticed a non tender tumour in the left breast, which had become enlarged. The mass was about the size of an orange and well defined although somewhat irregular with soft alternating elastic and firm areas. The skin was slightly stretched but not adherent to the tumour. The level of the nipple was slightly raised.

Some subcutaneous veins were visible but were not dilated, the largest just permitting the introduction of a polythene catheter and the injection of contrast medium (Fig 2). A few normal subcutaneous veins were filled, while the tumour and its surroundings remained avascular. Needle biopsy produced pus like fluid and operation revealed an encapsulated abscess. The absence of any demonstrable vascular connection between the subcutaneous veins and the tumour should possibly have permitted the exclusion of a cystosarcoma. The avascularity on the other hand obviously suggested an abscess.

Discussion

Cystosarcoma phyllodes are uncommon fibro-epithelial tumours of the female breast that may occur at any postpubertal age although usually in the fourth decade of life. They are related etiologically to the mammary fibroadenomas, with their maximum frequency about ten years earlier. Most of the cystosarcomas develop from pre-existing fibroadenomas but there is evidence that they occasionally may also arise de novo, without a precursory tumour. The cystosarcomas may vary in size, the smallest may measure about 1 cm, and the largest can be enormous. In spite of the term 'sarcoma' nine-tenths of the tumours are clinically innocuous while the remaining tenth behaves like highly malignant mesenchymal tumours, leading to death from general metastases, sarcomatous in character. Dilated and tortuous subcutaneous veins over, and in the vicinity of, the medium sized and large tumours may be a prominent feature and are apparently due to the transit of a considerable amount of blood. These tumours are thus highly vascularized, in fact most of the growths observed by the author including two that were malignant were found to be rich in vessels. The basic conditions for successful angiographic (phlebographic) examinations thus seem to exist.

Phlebography in the present case disclosed that the tumour was extremely

CYSTOSARCOMA PHYLLODES DIAGNOSED BY SUBCUTANEOUS MAMMARY PHLEBOGRAPHY

by

FRANZ PAUL PROBST

The diagnosis of tumours or tumour like conditions of the female breast rests essentially on the histologic or cytologic examination of material obtained by excisional, incisional or needle biopsy. The only roentgenologic contribution of importance to the diagnosis of these lesions is mammography, a method not in general use. However, one of the cases now reported indicated that one kind of bulky tumour of the breast is accessible to the angiographic diagnosis: the cystosarcoma phyllodes. The value of subcutaneous mammary phlebography is further demonstrated in the second case in which the 'tumour' was clinically indistinguishable from a cystosarcoma.

Case reports

Case 1 Unmarried woman, aged 29 years, who for 8 years had been aware of a lump in the right breast, the size of which had remained unchanged. About 3 months prior to admission the tumour commenced gradually to increase in size. The patient had no other symptoms. On examination, the right breast was larger and more pendulous than the left. A lobated tumour, about 9 cm in diameter, lay centrally in the breast. The tumour was relatively soft in some parts and firm or elastic in others, it was not attached to the pectoralis fascia or the overlying skin. Several enlarged veins covered the mass, these were drained by a vein that disappeared in the upper parasternal region (Fig. 1a).

Submitted for publication 28 August 1969



Fig 2 Case 2 Mammary abscess subcutaneous mammary phlebography. The mass is avascular and thus probably not a cystosarcoma

vascular and had defined borders. The sharpness of its delimitation, particularly against the thoracic wall, is of importance from the prognostic and surgical point of view, since it excludes an infiltrative growth into the surroundings and facilitates planning of the operation. However, the angiographic features cannot permit the exclusion of possible malignancy as malignant foci within such tumours may be small and difficult to detect even on careful histologic examination of the entire tumour. It is impossible to say anything about the 'specificity' of the angiographic features as no other cases examined by this method exist. However, it appears not unlikely that other cystosarcomas may behave in a similar manner. If further experience should indicate that phlebography of cystosarcomas is pathognomonic, the need for biopsy may be avoided and the risk of dissemination in those cases that harbour malignant tissue diminished.

Fig 1 Case 1 Cystosarcoma phylloides. a) Tumour in the central part of the right breast changing its contour. Large subcutaneous veins are present. b) c) and d) Subcutaneous mammary phlebography. Dense network of intratumoral veins. Surface veins radiate towards larger collecting vessels which are drained by one large and several small efferent veins. Optimal tangential view (d) defines a sharp border of the tumour against the thoracic wall and indicates no infiltration into the wall.



a



b



c



d

Fig 1 (for legend see opposite page)

FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR PROF OLLE OLSSON),
THE UNIVERSITY HOSPITAL, LUND, SWEDEN, AND THE DEPARTMENT OF RADIOLOGY
(DIRECTOR PROF CLAUDE H WILLIAMS), UNIVERSITY OF FLORIDA COLLEGE OF
MEDICINE, GAINESVILLE, FLORIDA, U S A

ORAL CHOLECYSTOGRAPHY

Experimental investigation and clinical comparison of
70 mm film and full scale radiography

by

RAGNAR JENSEN and JURI KAUDE

In oral cholecystography compression spot films under fluoroscopic control usually project the gall bladder free from overlying intestinal gas. It may be necessary to obtain additional supine or prone films with the overhead tube or with horizontal beam and patient in the right decubitus position. A correct diagnosis with the conventional method can be established in approximately 93 to 98 % of cases (JOHNSON & HARREL 1935, GOOD & KIRKLIN 1937, OLSSON 1939, WICKBOM & RENTZHOFF 1955, BAKER & HODGSON 1958, ALDERSON 1960 and others).

Fluorography with 70 mm film from the output screen of the image intensifier may replace full scale spot films in many roentgendiagnostic procedures (SAMUEL & SUMERLING 1964, WOHL & KOEHLER 1965, ELMER 1967, KAUDE 1967, 1968, COLLARD 1969, KAUDE & REED 1969, KAUDE & SILSHER 1969, and others). The methods has been considered diagnostically inadequate in oral cholecysto-

Part of this work was carried out at the University of Florida College of Medicine where J.K. acted as Visiting Assistant Professor 1967-1968. Submitted for publication 16 December 1969.

SUMMARY

Two cases of lesions of the breast examined by subcutaneous mammary phlebography are reported. In one case the lesion contained numerous pathologic vessels and proved to be a cystosarcoma, and in the other the mass was entirely avascular and was produced by an abscess. The significance of vascularization and the value of angiography are discussed.

ZUSAMMENFASSUNG

Zwei Fälle von Läsionen der weiblichen Brust, die mit subkutaner Phlebographie untersucht wurden, werden beschrieben. Die Läsion in einem der Fälle hatte zahlreiche abnormale Gefäße und erwies sich als ein Zystosarkom, im zweiten Falle war die Läsion völlig avaskular und war durch ein Abszess verursacht worden. Die Bedeutung der Vaskularisation und der Wert der Angiographie werden diskutiert.

RÉSUMÉ

Présentation de deux cas de lésion du sein examinées par phlébographie mammaire sous-cutanée. Dans un de ces cas, la lésion contenait de nombreux vaisseaux pathologiques et se révélait être un cystosarcome phyllode. Dans l'autre cas, la masse était entièrement avasculaire et était produite par un abcès. L'auteur examine l'intérêt de la vascularisation et la valeur de l'angiographie pour le diagnostic.

REFERENCE

PROBST F. P., WESTLING P. and ALM P. O.: Cystosarcoma phyllodes. To be published in *Acta radiol. Ther. Phys. Biol.*

ORAL CHOLECYSTOGRAPHY

Experimental investigation and clinical comparison of
70-mm film and full-scale radiography

by

RAGNAR JENSEN and JURI KAUDE

In oral cholecystography, compression spot films under fluoroscopic control usually project the gall bladder free from overlying intestinal gas. It may be necessary to obtain additional supine or prone films with the overhead tube or with horizontal beam and patient in the right decubitus position. A correct diagnosis with the conventional method can be established in approximately 93 to 98% of cases (JOHNSON & HARREL 1935, GOOD & KIRKLIN 1937, OLSSON 1939, WICKBOM & RENTZHOJ 1955, BAKER & HODGSON 1958, ALDERSON 1960, and others).

Fluorography with 70 mm film from the output screen of the image intensifier may replace full scale spot films in many roentgendagnostic procedures (SAMUEL & SUNERLING 1964, WOHL & KOEHLER 1965, EIMER 1967, KAUDE 1967, 1968, COLLARD 1969, KAUDE & REED 1969, KAUDE & SELLNER 1969, and others). The methods has been considered diagnostically inadequate in oral cholecysto-

Part of this work was carried out at the University of Florida College of Medicine, where J. K. acted as Visiting Assistant Professor 1967-1968. Submitted for publication 16 December 1969.

graphy and inferior to full-scale radiography (ELMER 1967, BECKING & HUPSCHER 1968, LINDQVIST 1969), or else the use of 70-mm fluorography has not been recommended in expectation of further improvements in the quality of image intensifiers (COLLARD 1969). However, exact experimental or clinical comparisons of 70-mm fluorography and full scale radiography in examinations of the gall bladder, using geometric or electronoptic magnification, have not earlier been presented.

The main advantages of 70 mm fluorography over full-scale radiography — the short exposure time and the low doses to the patient — are not so important in cholecystography, with little or no movement in the object and a small field well removed from the gonadal region. However, 70 mm fluorography in oral cholecystography becomes increasingly interesting with the use of remotely controlled diagnostic equipment (JUTRAS & DUCKETT 1958, FEDDEMA 1960, 1962, 1965, and others) and with fluoroscopic-fluorographic equipment without interposed full scale spot film holder (KAUDE 1968, FENZ 1969, HODGES & KAUDE).

As a link in a series of comparisons of full scale radiography and 70 mm fluorography, we have investigated the diagnostic accuracy of the latter in experimental studies with a gall bladder phantom, using a small focal spot and geometric and electronoptic magnification, and compared the method with full-scale radiography at oral cholecystography in routine clinical work.

Equipment Both the experimental and clinical investigations were performed with two different types of equipment.

With the use of a three-phase generator and a remotely controlled ring stand the focal spot was 0.6 mm. Spot films were obtained from the output screen of a 23 cm/12.5 cm (9"/5") image intensifier with a Philips 70 mm camera at 60, 70, 80, 90 and 100 kV (in clinical work usually at 70 to 90 kV). Exposure control was automatic. The 70-mm fluorograms were made on Gevaert Scopix HD film. Using a processor of roll type (Profexray), the films were developed at 78° F in Du Pont D-90 for 75 seconds to a gamma of about 1.1 to 1.2. The total processing time was 5 minutes and 15 seconds. Full-scale roentgenograms were made on Gevaert Curix RP films (acetate base) with Siemens Safir universal screens and processed in Kodak RP X Omat. The time of development in the latter was one minute at 99° F. The total processing time for full scale roentgenograms was adjusted to 3 minutes.

Fluoroscopy was performed with a transistorized Plumbikon television chain at 60 to 100 kV and 0.5 to 2 mA. Videofluoroscopy and filming with both methods were carried out at 1.3 times geometric magnification. 70 mm fluorography and fluoroscopy were also performed with 1.8 times geometric

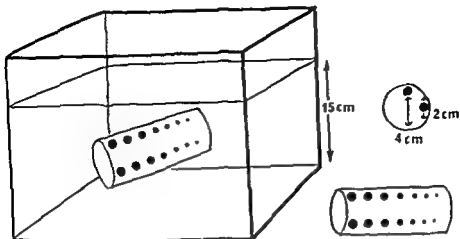


Fig 1 The gall bladder phantom placed in 15 cm water

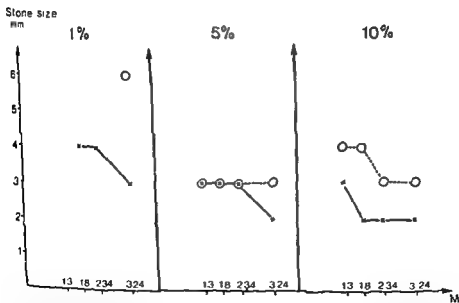


Fig 2 Smallest detectable stone size at videofluoroscopy with 0.6 mm focal spot and 23/12.5 cm image intensifier at different concentrations of contrast medium in the gall bladder

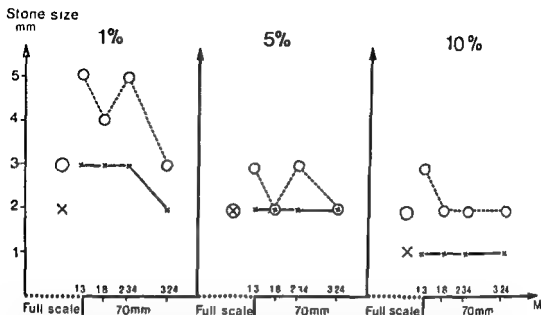


Fig 3 Smallest demonstrable stone size with 0.6 mm focal spot and 23/12.5 cm image intensifier. The total magnification (M) was 1.3 geometric only for full-scale. The curves represent for 20 mm contrast medium, full-scale (X) and 70-mm film (x—x), for 40 mm contrast medium, full-scale (O) and 70-mm film (o—o—o).

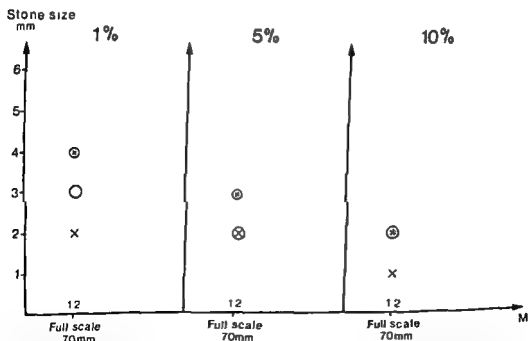


Fig 4 Smallest demonstrable stone size with 1.0 mm focal spot and 15 cm image intensifier. The magnification was 1.2 geometric. The curves represent for 20 mm contrast medium, full-scale (X) and 70-mm film (x—x), for 40 mm contrast medium, full scale (O) and 70 mm film (o—o—o).



Fig 5 Two stones in a gall bladder with high concentration of contrast medium a) 70 mm film 1.3 geometric magnification b) 70-mm film 1.8 geometric magnification c) 70-mm film obtained with 3.24 total magnification (1.8 geometric \times 1.8 electronoptic) d) Full scale film

magnification and with additional electronoptic magnification (total enlargement 2.34 or 3.24 times, respectively)

This type of equipment is not available in all roentgendiagnostic departments, or a 15 cm (6") image intensifier may be preferred to a 23 cm intensifier. Practical considerations may also require that only one type of processor be used for films of all sizes. Experimental and clinical investigations were therefore carried out also with a single phase 500 mA generator and a 1 mm focal spot with the least possible (1.5 to 1.2 times) geometric magnification. The 70 mm films were then made on Kodak Linagraph Shellburst (Estar base emulsion No 2474) or Kodak X Omat Fluorospot film. The full scale roentgenograms were obtained with overhead tube and Bucky diaphragm on Kodak RP-54 film, using medium speed screens. In this series, films of both sizes were processed in the Kodak RP X Omat in 90 seconds.

Experiments

Method A cylindric perspex container (length 120 mm, diameter 40 mm) simulated a normal sized gall bladder. Common, mixed type cholesterol, bile pigment and calcium salt stones, radiographically equivalent to water, were attached to the wall of the container at its greatest diameter (40 mm) and at a diameter of 20 mm (Fig 1). With this placement of stones, cholesterol polyps, or calculi, floating in an ordinary gall bladder and in a compressed or small



Fig 2 Gall bladder filled with small calculi, patient supine right posterior oblique position 70 mm films with following magnifications a) 13 geometric, b) 18 geometric c) 324 total magnification (18 geometric \times 18 electronoptic) The stones are better demonstrated in b) and c)

gall bladder were simulated. The sizes of the stones in both rows were 1, 2, 3, 4, 5 and 6 mm.

Two types of water-soluble contrast media were used to fill the gall bladder phantom: Cystokon (Mallinckrodt Pharmaceuticals, St. Louis) and Isopaque Cerebral (Nyegaard, Oslo). The contrast media were diluted to 1%, 5% and 10% concentrations. The 10% contrast medium simulated best the density produced in oral cholecystography (STAPLE & McALISTER 1965). The gall bladder phantom filled with the 1% contrast medium was barely visible at video-fluoroscopy. In clinical work, a gall bladder with such a low concentration of contrast medium and without demonstration of stones would have to be re-examined.

The gall bladder phantom was placed in a 15 cm high water phantom which simulated the soft tissues of an average patient. The primary collimation was the same as in clinical work. The field was reduced to include the gall bladder phantom with a narrow edge of water.

Results. The size of the smallest stone observed by the authors at fluoroscopy, or demonstrated with full-scale radiography and 70-mm fluorography, depended upon the contrast medium concentration in the gall bladder phantom and the magnification used. The perceptibility, in particular of stones in low contrast, was improved by the use of magnification techniques (Figs 2, 3 and 4).

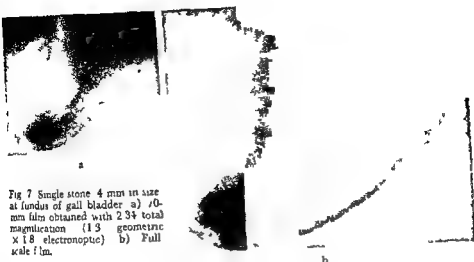


Fig 7 Single stone 4 mm in size at fundus of gall bladder a) 70-mm film obtained with 234 total magnification (13 geometric \times 18 electronoptic) b) Full scale film.

Clinical comparison

Material and Method Both full scale and 70 mm films were employed as a routine at the same session in 400 non-selected cases the gall bladder being filled with contrast medium and observed at videofluoroscopy. A total of 325 cases were examined at Lund and received eight tablets of Bilijodon Natrium (sodium salt of iopanoic acid, AB Leo, Helsingborg). The Gainesville material included 75 cases which were given 6 to 12 tablets of Telepaque (brand of iopanoic acid, Winthrop Laboratories, New York).

Excessive colon gas was eliminated by the intramuscular injection of 10 international units of vasopressin (COLLINS & ROOT 1936, GOTHLIN 1969).

The authors of the present paper reviewed both the 70 mm and the full-scale cholecystograms without knowledge of the conclusion made at the primary routine interpretation. Because our investigation aimed at an evaluation of the diagnostic accuracy of the 70 mm technique, the small films were interpreted first a diagnosis was made, and then the full scale films were read. All the examinations included in the series were technically of good quality and diagnostically conclusive. A magnifying viewer (MATTSSON 1953) was used with the 70 mm films in order to eliminate scattered light. The findings at operation became available for comparison in a number of cases.

Results A total of 322 of the 400 oral cholecystographies performed both with 70-mm fluorography and full scale radiography were normal. Biliary

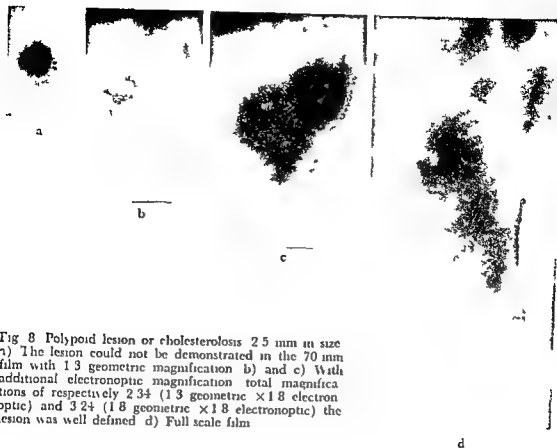


Fig 8 Polypoid lesion or cholesterosis 2.5 mm in size
 a) The lesion could not be demonstrated in the 70 mm film with 1.3 geometric magnification b) and c) With additional electronoptic magnification total magnifications of respectively 2.34 (1.3 geometric \times 1.8 electron optic) and 3.24 (1.8 geometric \times 1.8 electronoptic) the lesion was well defined d) Full scale film

calculi were diagnosed in 72 cases, polypoid lesions or cholesterosis in 5 cases and adenomyosis of the gall bladder in one case. The interpretation of the film of both sizes were in agreement in 398 cases (99.5 %).

There was disagreement of interpretation in two cases (0.5 %), both examined with the 23/12.5 cm image intensifier. Four stones, 1 to 2 mm in size, were not observed in the 70 mm films, these being superimposed upon the 12th rib. In comparison with the conventional films, the 70 mm films had been obtained in slightly different projections and slightly different degrees of compression. A further inspection of the films just revealed the stones, however. This finding was the only erroneous one made in relation to the 70 mm films. The patient later developed cholecystitis and at repeat examination no contrast filling of the gall bladder was obtained. Operation took place 2 years after the initial examination and the stones were then about 3 to 4 mm in size. In the second case, a 3 mm polypoid lesion in the gall bladder was thought to be present in the full scale films. This was not seen in the 70 mm fluorograms. The diagnosis at the routine interpretation of the full scale roentgenogram had been normal.

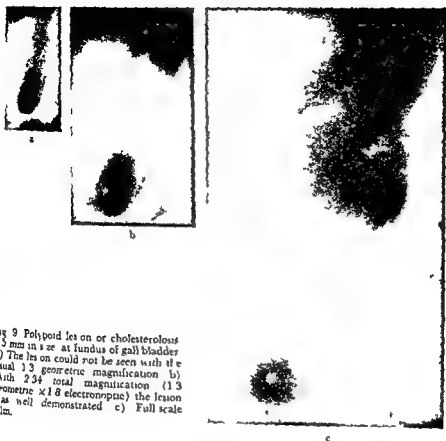


Fig 9 Polypoid lesion or cholesterolosis 5 mm in size at fundus of gall bladder a) The lesion could not be seen with the usual 13 geometric magnification b) With 234 total magnification (13 geometric \times 18 electronoptic) the lesion was well demonstrated c) Full scale film

cholecystogram'. At the repeat reading it became evident that the filling defect was a small gas bubble in the colon which lay over the gall bladder

Figs 5 to 9 present the findings in the comparison of 70 mm fluorography and 16 mm cine examinations have

the same or employing magnification techniques with 70 mm fluorography. The 70-mm films are reproduced in their original size

Discussion

It is evident that biliary calculi can often be diagnosed at videofluoroscopy (Fig 2). From a practical point of view, 70 mm filming is sufficient for documentation in such cases. The fluoroscopic diagnosis is improved when

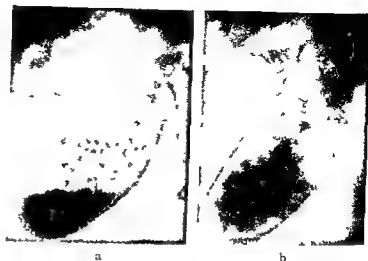


Fig 10 Gall bladder filled with stones up to 5 mm in size in 70 mm films obtained with 1 mm focal spot and 15 cm image intensifier using about 1.2 geometric magnification a) Erect b) Supine RPO film

magnification techniques are used, and this is particularly important when the contrast is low. In a 40-mm column of the 1% contrast medium at phantom studies, only the largest stones (6 mm) could be seen, and then only when electronoptic magnification was applied simultaneously with 1.8 times geometric magnification (total magnification 3.24 times).

The lower size limit for a detail that can be demonstrated with 70 mm films in clinical examinations with a water-soluble contrast medium is approximately one millimeter (BÅNG & KAUDE 1967). Stones of this size were the smallest tested and observed in studies with the gall bladder phantom. It was also shown that with the use of a 0.6 mm focal spot and geometric and electronoptic magnification, mixed-type gallstones could be demonstrated with the 70 mm technique to the same extent as with full-scale radiography (Fig 3).

In a recent comparison of 322 oral cholecystograms obtained with both 70-mm fluorography and conventional radiography, LINDQVIST (1969) reported, however, that in ten cases (3%) the diagnosis with 70 mm films was either erroneous or doubtful. In the present comparison, only one 70-mm examination, out of 400 cholecystograms, was misinterpreted and four stones 1 to 2 mm in size were not diagnosed. On the other hand, one examination performed with the full-scale technique (colon gas thought to be a polypoid lesion in the gall bladder), was incorrectly interpreted. This report was corrected at reviewing.

The difference in results between the study by LINDQVIST (1969) and the present comparison must depend on a difference in examination techniques at 70-mm fluorography. The focal spot in both investigations was 0.6 mm but LINDQVIST did not utilize geometric magnification because with the apparatus

available to lum compression could not be applied because of the increased distance between the patient and the input screen of the image intensifier. Nor had he access to an image intensifier permitting electronoptic magnification, the field size was also not reduced to a possible minimum by primary collimation.

Each of the these three factors is of great importance for the improvement of the image quality in 70 mm fluorograms. Figs 3, 8 and 9 indicate that in some cases the demonstration of small polypoid lesions or stones is not possible without magnification techniques.

Geometric magnification diminishes scattered radiation and improves the contrast and the resolution (FEDDEMA 1962, 1965, HOLM 1962, 1964, FEDDEMA & BOTDEN 1965). A small focal spot (0.6 or preferably 0.3 mm) is needed for geometric magnification. Electronoptic magnification reduces quantum noise and improves the resolution because an increase in the radiation of about 3.2 to 3.3 times is needed for this technique (HELLEAMP & ENDLICH 1965, KUM & VAN OVERIJAGEN 1965, FEDDEMA 1965). Because the field size is diminished, this increase of the radiation still does not result in an increase of the integral absorbed dose (FEDDEMA 1965).

By the simultaneous use of both magnification techniques the advantages are added and the object is moreover recorded in nearly its original size.

Finally a careful collimation of the field improves image quality and contrast by reducing not only scattered radiation but also unnecessary light scatter inside the image intensifier (BERANBAUM & LIGNON 1964, FEDDEMA 1965, MARQUERINCK & RECOLT 1965). The importance of a small field size and focal spot in the diagnosis of biliary calculi in full scale radiography has been well documented by VIRTAMA (1961). The effective use of primary collimation is even more important in a more sensitive recording system requiring a low exposure such as 70 mm fluorography.

No diagnostic errors were made in the series of 75 cases examined with a 10 mm focal spot and 15 cm (6") image intensifier (Fig 10). However, the smallest stones in this series were at least 2 to 3 mm in size and thus corresponded to the size of the smallest stones that could be demonstrated in phantom studies with the same equipment (Fig 4).

It is important to reduce focal unsharpness and to decrease the distance between the patient and the input screen of the image intensifier as much as possible with a focal spot of 1.0 mm or larger. This is more effectively accomplished when the interposed full scale spot film holder is removed (HODGES & HALDE 1968).

The importance of compression for equal distribution of contrast in the gall bladder (OLSSON 1939) is evident from Figs 2 to 4. The stone size demonstrated in films or observed at videofluorcopy was smaller when the stone was placed

in a 20-mm column than in a 40-mm column of contrast medium. Compression should consequently be applied even when geometric magnification is used to improve the detection of small stones.

Acknowledgement

The authors are indebted to Mr Lloyd M. Geyer of the S and H X-ray Company, Atlanta, Georgia, for his interest in this project and for help in the experimental investigations carried out at Gainesville.

SUMMARY

The diagnostic accuracy of 70-mm fluorography in examination of the gall bladder was investigated with the aid of a phantom and in a series of 400 oral cholecystographies. Biliary calculi and polypoid lesions could be demonstrated with 70 mm fluorography as accurately as by full scale radiography. The demonstrable stone size was inverse to the concentration of the gall bladder contrast.

ZUSAMMENFASSUNG

Die diagnostische Genauigkeit des 70 mm Bildverstärker Aufnahmeverfahrens bei Untersuchung der Gallenblase wurde mit Hilfe eines Phantoms und in einer Serie von 400 oralen Cholezystographien verwerlet. Gallensteine und polypoide Veränderungen in der Gallenblase konnten mit 70 mm Technik mit derselben Genauigkeit wie mit Grossformat Aufnahmeverfahren nachgewiesen werden. Die demonstrierbare Steingrösse stand im umgekehrten Verhältnis zu der Konzentration des Kontrastmittels im Gallenblasenphantom.

RÉSUMÉ

Les auteurs ont étudié la précision diagnostique de la radiophotographie en 70 mm dans les examens de la vésicule biliaire au moyen d'un fantôme et sur une série de 400 cholecystographies par voie orale. Ils ont pu mettre en évidence les calculs biliaires et les lésions polypoides avec autant de précision au moyen de la radiophotographie en 70 mm qu'au moyen des radiographies en vraie grandeur. Le diamètre des calculs que l'on peut mettre en évidence varie en sens inverse de la concentration du moyen de contraste dans la vésicule biliaire.

REFERENCES

- ALDERSON D. A. The reliability of telepaque cholecystography. *Brit J Surg* 47 (1960), 655.
 BAKER JR H. L. and HODGSON J. R. Oral cholecystography: an evaluation of its accuracy. *Gastroenterology* 34 (1958), 1137.
 BÄNG I. and KAUDE J. Hysterosalpingography: a comparative study with full size and 70 mm films. *Radiologe* 9 (1967), 269.
 BECKING H. B. and HUPSCHER D. N. 70mm image intensifier fluorography. *Medica mundi* 12 (1968), 95.

- BERANBAUM S L and LIGNON A J Routine gastrointestinal series with a 70mm sequence camera. Radiology 83 (1964), 337
- COLLARD M Les possibilités et les limites du format 70 mm en radiodiagnostic Étude expérimentale et clinique J belge Radiol 52 (1969), 63
- COLLINS E V and ROOT J C Elimination of confusing gas shadows during cholecystography by the use of pitressin J Amer med Ass 107 (1936), 32
- ELMER R A 70mm filming factors affecting image sharpness Radiology 89 (1967) 420
- FEDDEMA J X ray television and roentgen cinematography using a remotely controlled ring stand equipped with a 9 image intensifier Medica mundi 6 (1960) 57
- 70mm fluorography with a 9 image intensifier mounted on a remotely controlled ring stand Medica mundi 8 (1962) 7
- Enlargement techniques in televised fluoroscopic and photographic recording of a 9 image intensifier output screen in remotely controlled examinations Medica mundi 11 (1963) 67
- and BORDEN P J M Magnification techniques, especially geometric enlargement In Diagnostic radiologic instrumentation Modulation transfer function pp 382—397 Edited by R H Joseley JR and J H Rust Charles C Thomas Springfield Illinois 1963
- FENZ K J Reflexioner om 70mm s bildförstärkarfluorografins framtid (In Swedish) Paper presented at the 30th Congress of the Nordic Society for Medical Radiology Helsinki 1969
- GOOD C A and HARKLIN B R Influence of extrabiliary disease on function of gall bladder cholecystographic study Amer J Roentgenol 37 (1937), 346
- GOTHMAN J 8 ljun vasopressin för att eliminera tarmgas vid abdominell röntgendiagnostik (In Swedish) Paper presented at the meeting of the Swedish Society for Medical Radiology Stockholm 1969
- HELLERKAMP J E and ENGLISH B First experiences with an image intensifier with electronic enlargement Medica mundi 11 (1963) 9
- HODGES W C and KALDE J 70mm spot filming fluoroscopic fluorographic equipment without interposed full scale film holder To be published
- HOLM TH Röntgenkinematographie
— Some aspects of radiographic info
- JOHNSON I B and HARREL H C — , — 300 cases with comparison of operative findings in cases operated upon Radiology 25 (1935) 300
- JUTRAI A and DUCKETT G Roentgen diagnosis by remote control telefluoroscopy and cineradiography Medica mundi 4 (1958) 77
- KALDE J Clinical studies on image intensifier fluorography and cinefluorography Acta Univ Lundensis Sectio II No 18 (1967) C W K Gleerup Lund
- 70mm filming from output phosphor of image intensifier Postgrad med Radiol 44 (1968) 47
- r fluorography
- Clin. Pediat 8 (1969) 106
- KATIL W and VAN OVERHAGEN J W D A 9 inch x ray image intensifier with variable magnification Medica mundi 11 (1965) 1
- LINDQVIST M Kolecystografi med 70mm fluorografi (In Swedish) Nord Med III (1969) 575
- Personal communication

- MARQUERINCK J E and RECOURT A Image quality in TV fluoroscopy *Medica mundi* 11 (1965), 54
- MATTSSON O A magnifying viewer for photofluorographic films *Acta radiol* 39 (1953), 412
- OLSSON O Den perorala cholecystografiens tillförlitlighet (In Swedish) *Nord Med* 3 (1939), 2896
- SAMUEL E and SUMERLING M D An assessment of the use of the 70mm camera in radiological practice *Brit J Radiol* 37 (1964), 620
- STAPLE T W and McALISTER W H In vitro and in vivo visualization of biliary calculi *Amer J Roentgenol* 94 (1965), 495
- WICKBOM I and RENTZHOG U The reliability of cholecystography *Acta radiol* 44 (1955), 185
- VIRTAMA P Influence of certain physical factors on the radiographic demonstration of cholesterol gallstones *Acta radiol* 56 (1961), 193
- WOHL G T and KOEHLER P R Experience with a 70mm camera in image amplification fluorography *Clin Radiol* 16 (1965), 363

OCCURRENCE AND COURSE OF THROMBOSIS FOLLOWING PROSTATECTOMY

A phlebographic investigation

by

J BECKER, S BORGSTROM and G F SALTZMAN

It was long considered that the clinical signs of acute thrombosis of the lower limbs were so characteristic that a correct diagnosis could be made with a high degree of certainty. In an increasing number of publications, however, the infallibility of the clinical diagnosis is being questioned. It has now become obvious that if the clinical evidence alone is used as the basis for diagnosis, a great many cases of thrombosis will be missed and furthermore a considerable degree of overdiagnosis will occur. Effectively performed phlebographic examinations have been the main agents in revealing the inadequacy of the clinical diagnosis.

Most of the reports on phlebographic investigations dealing principally with the diagnosis of thrombosis have, it is true, demonstrated incomplete agreement between the clinical signs and phlebographic findings, but they can hardly be said to have increased the possibilities of assessing the incidence of thrombosis or of studying the course of a thrombosis already diagnosed. The reason for this is that in nearly all cases some form of clinical manifestation has been the indication

Submitted for publication 18 September 1969

for the phlebographic examination Only a few investigations have been described in which phlebography was carried out routinely in thrombosis prone materials (post traumatic cases) irrespective of whether clinical signs of thrombosis were present or not (BORGSTROM et coll 1965 1967, BERGVALL & HJELMSTEDT 1968 FREEARK et coll 1967) These materials clearly reveal that thrombosis producing no clinical signs or symptoms is not uncommon and that the thrombotic condition may be localized either to deep veins or to muscle veins

The subsequent course of thrombosis has been studied by phlebography by only a few workers, and in those cases in which this has been done the main object has been to investigate the effect of different forms of therapy MA & NISSEL (1959) and BERGVALL & HJELMSTEDT (1968) studied the recanalization process in deep vein thrombosis The phlebographic appearances of post thrombotic changes have been described in some detail It is considered that in most perhaps even in all cases, the condition leaves phlebographically demonstrable post thrombotic changes (HAECER 1965) No conclusive arguments to prove such a view seem to have been advanced however

It is now universally recognized that certain types of traumatic damage and surgical interventions predispose to the development of thrombosis It is generally a question of elderly patients who in the nature of things already run an increased risk of developing the condition It therefore seems likely that in some of the cases of thrombosis that have been diagnosed postoperatively the condition was present prior to the intervention Pre operative and postoperative phlebographies for purposes of comparison do not seem to have been carried out and it is thus not surprising that the views regarding the phlebographic appearances in acute venous thrombosis should be highly divergent (NYLANDER 1968, BORGSTROM et coll 1965, and others)

With these unsolved problems in mind a series of phlebographies were set up in connection with attempts to achieve better thrombosis prophylaxis following prostatectomy The problems investigated were (1) the thrombosis rate that could be demonstrated by phlebography after prostatectomy, (2) the location of the thrombi, (3) the extent to which the thrombi produced post thrombotic venous changes and the appearances of these changes, and (4) how often the thrombi diagnosed postoperatively were present before the intervention

Material The total material consisted of phlebographies performed on 367 legs in 187 cases It was compiled in connection with different experimental series set up in attempts to improve the thrombosis prophylaxis The observations relevant to the latter problem are to be published in another connection (BECKER et coll 1969) As no differences at all could be found in the incidence of thrombosis between the experimental series, either among the series themselves or

between the different series and control groups, the material has been treated as a unit

All the examinations were made in connection with transvesical prostatectomy, and the material may thus be considered homogeneous not only in regard to factors predisposing to acute thrombosis but also to the age distribution among the patients

Phlebography was always performed a short time after the operation, a bilateral examination was planned for all cases and in most instances could also be carried out. When no clinical signs of thrombosis existed, the phlebographies were performed not later than one month after the prostatectomy, most examinations were made within one to two weeks. In cases with clinically probable thrombosis, phlebography was carried out at once.

A follow up examination was performed in nearly all the cases in which thrombosis was present at the first postoperative phlebography, the interval between this and the earlier phlebography ranged from two months to two years. It was occasionally not possible to carry out a second examination.

Pre-operative phlebography was also performed on 110 legs in 56 cases. This was done in order to gain information on the incidence of pre-operatively manifest thrombosis as well as to be able to assess the course of any thrombosis that arose postoperatively in relation to the pre-operative status.

Methods All the examinations were performed in accordance with the method of ascending phlebography first introduced by GREITZ (1954). The method has been used by BORGSTROM et coll (1965) for thrombosis studies. A brief recapitulation of the technique will be given.

The patient is examined in a semi erect position. A dorsal vein of the foot is punctured percutaneously and 60 ml Urografin 45 % are rapidly injected. Films are exposed in two planes and cover the crus and a part of the thigh. The upper part of the thigh is examined only in the a p projection. This series is repeated so that two roentgenograms are exposed in each projection. No elastic bandage is used.

Thrombi appear as defects in the contrast filled veins. As ALMEN & NYLANDER (1964) have demonstrated, not all contrast defects in veins are caused by thrombi. BORGSTROM et coll have set up criteria that should be observed before a diagnosis of thrombosis is justified. We have found these to be adequate and have used them when diagnosing the condition. Briefly, they imply that the contrast defects should be distinctly demarcated, that they must have identical appearances in views taken at varying intervals after contrast injection, and that they must be visible in two different projections. All cases in the present material judged to have thrombosis fulfilled these requirements. For considera-

tions of space, examples of this have not been given in the illustrations but views giving information with more relevance to the questions studied in this paper have been included.

Results

The phlebograms were studied first from the aspects of the thrombosis rate and the site of the thrombi. The subsequent course of the disease was also investigated. An attempt was made in a small series to assess the significance of thrombi present pre-operatively as a possible source of error in the evaluation of thrombosis arising postoperatively.

Thrombosis rate. Clinical signs of thrombosis were present in 19 cases (10%). This rate tallies with the figures given for earlier series in which the assessment had been made on the basis of the clinical signs following prostatectomy. Phlebographic examination revealed thrombosis in 51 legs (14.7%) in 39 cases (21%). In one case, muscle vein thrombosis seemed highly probable but the contrast defect did not meet all the criteria that had to be observed. There was thus a definite discrepancy between clinical signs and phlebographic findings.

Only thirteen of the nineteen cases with clinical signs of the disease were verified as cases of thrombosis at the phlebographic examination. In one other case, a defect that suggested thrombosis was seen in a muscle vein but it did not meet all the criteria necessary for a definite diagnosis. In five cases there were no signs at phlebography to indicate thrombosis.

Clinically characteristic signs of pulmonary embolism were observed in three cases. Two of these patients died and necropsy confirmed the diagnosis of pulmonary embolism in both of them. These two cases require further comments. In one of them, bilateral phlebography 8 days after operation revealed nothing to suggest thrombosis. The patient died 13 days after the roentgen examination, and necropsy disclosed in addition to pulmonary embolism large thrombi in the femoral veins. In the other case, thrombotic changes in a muscle vein and a superficial vein (thrombophlebitis) were observed at phlebography 5 days after the intervention. The patient died 16 days after the roentgen examination and necropsy confirmed the presence of muscle vein thrombosis in addition to the pulmonary embolism, but it also revealed wide spread thrombosis of the femoral vein and pelvic veins on the same side.

In 166 cases there were no clinical signs of thrombosis but 26 of these proved to have phlebographically demonstrable thrombi during the postoperative course. In twenty four of the latter the condition was disclosed at the routine post-operative phlebographic examination. In addition one other case with a muscle



Fig 1 a) and b) Two small thrombi in muscle veins (\rightarrow) demonstrated 15 days after prostatectomy c) and d) Total regression 6 weeks later

vein thrombus in a clinically symptom free leg had clinical signs of, and phlebographically confirmed thrombosis in the other leg

It was stated under the heading material that the time interval between operation and routine postoperative phlebographies varied in the cases without clinical signs but that the longest interval was one month. An attempt was made to divide this material in different ways into cases with early and late phlebographies. No significant differences were found between these groups. It should be mentioned however that in two cases with negative phlebograms 9 and 16 days respectively after operation, extensive deep vein thrombosis was established later. The condition was diagnosed at phlebographies undertaken later because of clinical signs of thrombosis. In one case the diagnosis was made four and a half months after operation, in the other case deep-vein thrombosis was present just over one month after the intervention and at further phlebography a few months later it had progressed.

No difference in thrombosis frequency in relation to age was noted in this material. The average age of patients with and without thrombosis was almost identical 70 and 69 years respectively.



Fig 2 a) Thrombus in muscle vein (→) demonstrated 13 days after prostatectomy; b) Total regression 3 1/2 months later

Site and distribution of thrombosis The site and distribution of the thrombi were investigated in the fifty one cases in which thrombosis was diagnosed by phlebography

In most of the cases (47 legs) thrombi were present in the muscle veins of the lower limbs (Figs 1 to 5) and in 11 of these legs there were also thrombi in the deep venous stems in addition to those in the muscle veins. Thus, muscle vein thrombosis alone was observed in 36 legs

Isolated thrombus formation in one of the deep venous stems was noted in only four cases (Figs 7 and 8). None of these deep thrombi blocked the affected vessel completely, the contrast medium could always pass to one side of it. Not a single case was observed in this material in which all the contrast medium presumably passed through superficial veins

In two of the cases in which the thrombi were classified as lying in deep venous stems their relations to the popliteal vein were such that they were interpreted as originating in all probability in the short saphenous vein (Fig 11)

In order to see whether there was any relation between the site of the thrombi and the clinical signs of thrombosis the cases were divided into two groups. Clinical manifestations were present in 10 legs with phlebographically confirmed pure muscle vein thrombosis, while in 26 cases with pure muscle vein thrombosis there were no clinical signs at all. Of the ten cases with clinical manifestations, nine had local signs in the legs, while one patient died of pulmonary embolism without having any leg signs



Fig 3 Muscle vein thrombosis (→) demonstrated 13 days after prostatectomy (b) Two months later (c) the thrombosed vein has resumed the appearances seen at pre operative phlebography (a)

Five among the fifteen cases with deep venous thrombosis with or without thrombi in muscle veins had clinical signs, these were in the legs in four instances and in the fifth the patient died of pulmonary embolism.

Thus, in this material clinical signs were present three times more often in cases with thrombosis of the deep venous stems than in those in which the condition was confined to the muscle veins, although even in the former they were not common.

Further course of acute postoperative thrombosis Additional phlebographies were performed in 40 cases in order to study the subsequent course of acute postoperative thrombosis that had been confirmed by phlebography. In the other cases with thrombosis, such an examination could not be carried out, either because of death from pulmonary embolism, death from some other cause, refusal on the part of the patient to submit to another examination, or failure in the attempts to perform further phlebography.

The time interval between the repeat phlebography and the examination at



Fig 4 Muscle vein thrombosis (→) demonstrated 17 days after prostatectomy (b) Three months later (c), the thrombosed veins have resumed the appearances demonstrated at preoperative phlebography (a)

which thrombosis had been diagnosed varied considerably. The shortest period was three weeks and the longest nearly two and a half years, with an average of thirty-three weeks.

The results obtained from the further phlebographies showed considerable variations. Total regression, with an apparently completely normal venous system, was observed in sixteen legs, while twenty-four phlebograms presented different types of pathologic changes in the veins. These variations seem to justify a closer analysis.

A. Total regression of fresh thrombi. Among the sixteen cases in which the thrombi had disappeared without leaving any traces there were cases both of muscle vein thrombosis (Figs 1 to 4) and of thrombi in the deep venous stems (Figs 7 and 8). Total regression of deep-vein thrombosis occurred in seven cases. This figure means that total regression of fresh thrombi in deep venous stems was definitely more common than complete disappearance of such thrombi in muscle veins. Valves that appeared completely normal were observed in many of the previously thrombosed deep veins (Figs 7 and 8). The veins had in most cases decreased in diameter after the thrombus had disappeared. The time interval between the two postoperative phlebographies in these cases with total regression varied between four weeks and one and a half years, with an average of five months. The patient in whom this regression occurred as early as four weeks after

the first examination had had thrombi both in muscle veins and in a deep venous stem. The thrombi had disappeared within three months of the time when they were diagnosed in 8 cases, in other words half the number with total regression.

Clinical signs of thrombosis were present in only two of these sixteen cases when the condition was diagnosed by phlebography. It was in both instances a question of thrombi in deep veins of the lower limb, in one of which muscle-vein thrombosis was also present.

It may be worth mentioning in this connection that heparin therapy had in most cases been instituted as soon as a thrombus was detected. This was omitted in four cases, but total regression occurred in three of them.

dangerous to describe vessels that have been the seat of blood clots as completely normal. The evidence can hardly be regarded as conclusive unless pre-operative phlebography has been performed. This question will again be considered when describing the series in which both pre- and postoperative examinations were carried out.

B. Persisting pathologic venous changes after acute thrombosis. Cases of both muscle vein and deep-vein thrombosis were encountered among the twenty-four legs in which some form of change was still present at repeat phlebography. The number of legs with thrombi in muscle veins was eighteen, while in six legs thrombi in deep venous stems as well as in muscle veins had been demonstrated.

The time interval between the two postoperative phlebographies varied in this group from three weeks to about two and a half years, with an average of ten months. Thus, the period was on an average twice as long as in the group with total regression of verified thrombosis.

The persisting pathologic changes may be divided into smaller groups.

- 1 *Irregular vein wall.* No thrombus remnants were seen in the relevant vein in eleven legs at the second phlebography although the venous walls were clearly irregular (Fig. 5). The severity of these changes varied, in some instances they were so slight that it is doubtful whether they would have been noticed if it had not been known that the vein had previously contained a thrombus. These affected veins were as a rule narrower than at the examination when the thrombus was detected. Apparently normal valves were observed in two cases.

- 2 *Persisting thrombus remnants.* Small remnants were present in six legs at the second postoperative phlebography (Fig. 6). The thrombus had in every instance decreased to a fraction of its original size, the vein walls were noticeably irregular in all these cases. Apparently normal valves were present in one case in a previously thrombosed part of a vein.



Fig 4 Muscle vein thrombosis (→) demonstrated 17 days after prostatectomy (b) Three months later (c), the thrombosed veins have resumed the appearances demonstrated at pre operative phlebography (a)

which thrombosis had been diagnosed varied considerably. The shortest period was three weeks and the longest nearly two and a half years, with an average of thirty three weeks.

The results obtained from the further phlebographies showed considerable variations. Total regression, with an apparently completely normal venous system, was observed in sixteen legs, while twenty four phlebograms presented different types of pathologic changes in the veins. These variations seem to justify a closer analysis.

A Total regression of fresh thrombi. Among the sixteen cases in which the thrombi had disappeared without leaving any traces there were cases both of muscle vein thrombosis (Figs 1 to 4) and of thrombi in the deep venous stems (Figs 7 and 8). Total regression of deep vein thrombosis occurred in seven cases. This figure means that total regression of fresh thrombi in deep venous stems was definitely more common than complete disappearance of such thrombi in muscle veins. Valves that appeared completely normal were observed in many of the previously thrombosed deep veins (Figs 7 and 8). The veins had in most cases decreased in diameter after the thrombus had disappeared. The time interval between the two postoperative phlebographies in these cases with total regression varied between four weeks and one and a half years, with an average of five months. The patient in whom this regression occurred as early as four weeks after



Fig 7 a) Deep-vein thrombosis (→) demonstrated 18 days after prostatectomy b) Total regression 2 years later. The values in the thrombosed area are apparently normal

thrombosed venous segment had become noticeably larger but part of the previously thrombotic area in the respective vein was now free from clots. In the third case, the thrombus observed at the first examination had disappeared but had left signs of vein wall irregularity. A further thrombus in a muscle vein had however developed in a vein that had presented no evidence of involvement at the first examination.

Comparison between pre- and postoperative phlebographies The need for pre-operative phlebographies became increasingly apparent as the investigation proceeded. Two questions in particular demanded an answer, viz if all the thrombi demonstrated after the operation had really arisen postoperatively, or if some of them had been present earlier, and, further, whether the condition interpreted as total regression of a thrombosis was a complete return to the prethrombotic venous anatomy.

A total of 110 pre-operative phlebographies were therefore carried out in cases in which it was intended later to perform postoperative phlebography. The pre-operative examination was usually performed a week before the operation. Any thromboses detected were also examined by further phlebographies. Although the material is small, a few observations seem worth mentioning.

Ninety-four of these pre-operative phlebographies could be used for a comparative study, as the examination series could be followed through in these cases. Postoperative thrombosis arose in eleven of these legs, in four of them the thrombi disappeared completely and the veins reverted to exactly the same appearances



Fig 5 (above) a) Muscle vein thrombosis (→) demonstrated 18 days after prostatectomy b) Two years later, no thrombus remnants but the vein is narrower and has irregular walls

Fig 6 (right) a) Large thrombus in muscle vein (→) demonstrated 8 days after prostatectomy b) Five months later the vein contains small thrombus remnants (→) and is narrower



As these thrombus residues might conceivably represent a phase in development towards further regression, the time interval between the phlebographies was investigated. In two instances the period was short (three and six weeks respectively) so that the possibility of continued regression cannot be excluded. In the other four cases, the period was much longer, namely three and a half months, just over five months, one year, and nearly two and a half years, respectively.

3 Progress of thrombi In three legs, in which contrast-encircled 'floating' thrombi were seen at the first postoperative phlebography, no contrast medium was visible in the vessel in question at the second examination. The filling defect was in all these cases much larger than the thrombus demonstrated at the first phlebography.

4 Regression and progress of thrombi In three legs, in which thrombi were present at the first examination, the second phlebography indicated that both regressive and progressive changes had taken place. In two of these, the



Fig 9 a) and b) Thrombus (→) in the popliteal vein one month after prostatectomy c) and d) Total regression 6 months later

Thrombi arising at a late stage after the operation Three of the thrombosis cases in the material differed noticeably from the others and deserve a more detailed description. In all three, routine postoperative phlebography 8, 9, and 16 days after the prostatectomy demonstrated apparently normal conditions. One of these patients died 13 days after postoperative phlebography. Necropsy revealed pulmonary embolism and widespread thrombosis of both femoral veins. In this case the interval between operation and death was 21 days, and the connection between the operation and the thrombosis is thus obvious. The second patient developed clinical signs of thrombosis 16 days after the first negative postoperative phlebography. Further phlebography carried out immediately showed a thrombus in the popliteal vein, and another examination 5 months later indicated that no contrast medium passed through any of the deep leg veins. The interval between the intervention and the demonstration of thrombosis was just over one month and the connection between the operation and the thrombosis must therefore be assessed as probable. The third patient had clinical signs of thrombosis a little over 4 months after a negative postoperative phlebography. A second phlebographic examination at that time disclosed that no passage of contrast medium occurred through the deep leg veins. As the time interval was long it is not certain whether there was any connection between the operation and the thrombosis. This possibility cannot however be excluded as the condition may have developed gradually over a long period without producing clinical signs.



Fig 11 a) and b) Thrombus (→) in the popliteal vein 14 days after prostatectomy c) and d) Total regression 8 months later Valves are visible

as before the intervention (Figs 3, 4 and 10), and the other seven legs presented signs of residual changes of varying severity

Isolated thrombi were observed in two legs before the operation in one instance it was a muscle vein thrombosis (Fig 12) and in the other a thrombo phlebitis. The postoperative venous status was unchanged sixteen and thirty one days respectively after the first examination in both these cases. Extensive changes in the veins, with the typical post thrombotic appearances, were observed pre operatively in four legs, in all four the condition was unchanged postoperatively 4 to 23 days after the first examination. A similar case was also observed in the group of postoperative phlebographies in which no pre operative examination was performed, the condition was still unchanged at further phlebography 6 months after the preceding one

In the remaining 77 legs, neither the pre operative nor the postoperative phlebography revealed any pathologic changes, both the contrast filling and the anatomic appearances of the veins were identically the same in both examinations



Fig 11 a) Thrombus (→) growing from the small saphenous vein into the popliteal vein 15 days after prostatectomy b) Total regression on 6 weeks later

Fig 12 a) Muscle vein thrombosis (→) demonstrated at pre-operative phlebography b) Unchanged condition 30 days after prostatectomy

Our material differs considerably from most of the earlier thrombosis series studied by phlebography because in our patients postoperative phlebographies were carried out irrespective of whether they had had clinical signs of thrombosis or not. In most of the previous investigations some form of clinical manifestation was the reason why phlebography was undertaken. There are a few exceptions: a series of fractures of the upper end of the femur, published by BORGSTROM et coll., a material of tibial fractures described by BERGVALL & HJELMSTEDT and a material of mixed traumas presented by FREELARK et coll. The first of these series resembles the prostate material in our series as regards incidence and distribution of the condition.

The reliability of the phlebographic method in the diagnosis of thrombosis has been much discussed in recent years. It now seems to be generally recognized that the method, irrespective of the technique employed, is always superior to the purely clinical means of examination. The technique used in our cases has been proved by GREITZ to give the best conditions for producing homogeneous contrast filling of the venous system of the lower limbs. BORGSTROM et coll. have advanced arguments indicating that the method is reliable for demonstrating thrombosis.

Our group, in which both pre- and postoperative phlebographies were carried out, seems to corroborate the reliability of the method. Had the contrast defects



Fig 10 Thrombus (\rightarrow) at junction between popliteal and femoral veins (b) 13 days after prostatectomy. Two months later the thrombosed vein has resumed the same appearance (c) as at pre operative phlebography (a) Small saphenous vein widened at latest examination (c)

Discussion

The material on which this investigation is based was selected. All the patients had undergone prostatectomy. This implies that the series is homogeneous as regards factors predisposing to thrombosis, and relatively homogeneous as to age distribution. On the other hand, it does not throw much light on the manifestations and course of the thrombosing process in the wider sense. Both the incidence and distribution of the disease might be different in a material of another composition, also the relation between clinical and phlebographically demonstrated thrombosis might not be the same as in other series.

the other hand, from those described by NYLANDER (1968) and by HÆGER & NYLANDER (1967). In the latter report it was stated: 'acute thrombosis of the lower leg appears in the radiograms as nonvisualisation of all the deep veins of the leg under the crural fascia'. These authors mentioned the 'knot-hole phenomenon' and the 'derivated flow phenomenon' as other significant findings. NYLANDER believed that non-filling of the deep crural veins is as a rule a transient phenomenon caused by reactive edema, with a secondary increase in pressure which prevents passage through the deep veins. Non-filling of all the deep veins was observed only occasionally in our series, and occurred only in those cases in which the thrombi progressed over a long control period. In addition, there were a few cases with characteristic stationary post-thrombotic changes. The other features mentioned by NYLANDER were not observed in our cases. Dilatation of superficial veins was not seen in connection with the demonstration of a fresh thrombus but was observed in one or two cases after the thrombus had disappeared (Fig 10).

The difference between the present observations and those of NYLANDER must be explained. NYLANDER described his thromboses as acute on the grounds that the phlebographies had been carried out as soon as clinical signs were noted. We used the term 'fresh thrombosis' because in most of our cases in which there were no clinical signs it could not be decided exactly when the thrombus had been formed. The fact that NYLANDER described two cases in which contrast-encircled thrombi were present a few days after a stage in which no filling of the deep venous stems was obtained lends support to the view that a time factor might possibly explain the discrepancy. That this difference could be the sole explanation of the phlebographic discrepancies seems unlikely however, since ZACHRISSON's material agrees closely with NYLANDER's series as regards indications but closely resembles our material in the phlebographic findings. Clinical signs in our series also led to the immediate performance of phlebographic examinations but the phenomena described by NYLANDER were not observed.

In all probability, NYLANDER's observations on the one hand and those of ZACHRISSON and the present authors on the other, reflect differences in the composition of the respective primary materials. It is not unlikely that prostatectomy is seldom complicated by thrombotic manifestations with such a relatively dramatic course as those in NYLANDER's series. Even in the early days, BAUER pointed out that thrombi encircled by contrast medium, such as those dominating the present material, do not as a rule produce clinical signs. It seems hardly likely that the highly 'thrombosis-minded' clinicians in our team would have consistently failed to notice signs of thrombosis if our cases had passed a stage with the phlebographic changes described by NYLANDER.

The literature contains only a few reports on the course of the thrombosing

which we interpreted as thrombi been artefacts due to technical factors in the examination then (1) contrast defects in large numbers would have been seen at the pre-operative examinations and (2) defects observed at the pre operative examinations would as a rule have disappeared or altered in appearance in the postoperative phlebograms. This did not occur however. The number of contrast defects in the pre operative films was small and much lower than in the post-operative examinations. The defects seen before the operation and interpreted as thrombi or components in a post-thrombotic condition, had exactly the same appearances at the postoperative examination carried out shortly afterwards. These observations provide support for the view that the phlebographic technique used by us is a reliable aid in the diagnosis of venous thrombosis.

The system with routine postoperative phlebographies does not however constitute a guarantee that a warning signal will be obtained before pulmonary embolism. Our series afforded no definite indication regarding the best time for the performance of phlebography following operation to be sure of detecting a thrombus.

As to the incidence of thrombosis it may be mentioned that the number of cases of thrombosis diagnosed by phlebography was nearly twice as high as the number disclosed by clinical signs. This demonstrates quite plainly the superiority of phlebography as a diagnostic method. A somewhat remarkable observation is that a certain element of clinical over-diagnosis seems to occur. This was less apparent in our material than the clinical under-diagnosis. HAEGER considered however that the risk of over diagnosis is considerable. The clinical signs are so uncharacteristic and ambiguous that a certain degree of clinical over diagnosis is hardly surprising. To this may be added the possibility that small thrombi, if not larger ones, that are attached insecurely to the vessel wall may break loose and move away out of range for a phlebographic diagnosis without necessarily producing any notable clinical manifestations.

The appearances and site of the thrombi differed considerably in our cases from the conditions described in some other investigations. Most of the thrombi in our series appeared, both in muscle veins and in deep venous stems, as filling defects encircled by contrast medium. Thus, the appearances corresponded to the 'floating thrombi' described by BAUER (1940), LINDBOM (1952) and BORGSTROM et coll (1965). Most of the thrombi in our cases were located in muscle veins. As regards appearance and localization, our series resembles those described by BORGSTROM et coll and by ZACHRISSON. The selection of the material in our series differed from that in the two latter investigations. It should be emphasized that ZACHRISSON always insisted upon having some form of clinical manifestation as an indication for phlebography. The present material diverges radically, on

Conclusions

Our investigations have provided further support for the view that the technique for ascending phlebography introduced by GREITZ is a reliable one in the diagnosis of thrombosis in the legs. Postoperative phlebography has clearly demonstrated that the clinical diagnosis of thrombosis is unreliable. Approximately half the number of cases with phlebographically demonstrated thrombi in our material had no clinical signs. A certain amount of clinical over-diagnosis also occurred.

A negative phlebogram constitutes no definite guarantee that the patient will not develop pulmonary embolism. As the interval between the operation and the development of thrombosis seems to vary, it is difficult to give any indication as to the best time for performing postoperative phlebography.

Thrombosis is diagnosed by phlebography in over one fifth of cases of prostatic carcinoma. The thrombi are situated in the superficial muscle veins or deep venous stems of the leg or in the muscle veins or deep venous stems of the thigh. The thrombi appear as contrast encircled defects in the respective veins. Non filling of all the deep veins was an uncommon finding in this material, it was observed only in those cases in which the thrombosis had progressed over a long observation period.

An acute floating thrombus disappears without trace in over one third of all cases. It is not possible to say how rapidly this takes place but it occasionally occurred within 4 weeks and total regression within 3 months was often recorded.

More than half the number of thrombi leave varying residual changes. Small irregularities in the vein wall were common in the area where the thrombus had been situated. Remnants of thrombi were sometimes seen, and in a few cases the thrombotic changes had progressed. Regressive and progressive changes were sometimes present side by side in the same thrombosed region.

A series of pre operative phlebographies indicated that it cannot be categorically concluded that all postoperatively diagnosed thrombi have arisen after the operation.

Pre-operative studies provided further support for the view that thrombi may disappear altogether. In this connection phlebograms obtained before the operation were valuable in the assessment of the normal anatomy of the veins.

SUMMARY

Postoperative thrombosis has been studied in 519 phlebograms from 367 legs in 187 cases following prostatectomy. The diagnostic reliability of the clinical examination as compared

process. It has long been known that certain types of thrombosis lead to post thrombotic conditions, especially in the form of extensive obliteration of deep venous stems, deformation of the walls of the veins and new formation of small tortuous vessels. It is also known that pulmonary embolism not seldom occurs in cases in which the primary thrombosis has not given rise to symptoms. As mentioned above, NYLANDER noted in a few cases a rapid development from a stage of non filling of the deep veins to a condition that could best be described as floating thrombi. HAEGER has maintained that a negative phlebogram long after a thrombosis has been suggested clinically is a sign that the suggestion was unfounded. MAI & NISSEL (1959) and BERGVALL & HJELMSTEDT (1968) studied the recanalizing course in deep thrombosis of the lower limbs after tibial fractures and reported that the process is very slow. No other important systematic studies of the subsequent course of phlebographically verified thrombi seem to have been published.

Our cases varied greatly as regards the continued course of the thrombosing process as far as this could be judged at repeat phlebography. Total regression was not uncommon and was observed in over one third of the cases. Although most of the cases in which thrombi were diagnosed received heparin, total regression was also observed in a few cases that had not received the drug. In a further one fourth of the cases, there were no signs of persisting thrombosis but the walls in the previously thrombosed veins were irregular. Thus, it seems as if approximately half the number of thrombi in a thrombosis series of the present type disappear so completely that a subsequent, isolated phlebographic examination affords no evidence of their having been present. Regression occurred relatively rapidly in our cases, in half of them within 3 months.

The other cases presented a wide diversity of changes, from small residual thrombi to thrombi that had progressed to conditions resembling earlier, well known post thrombotic states. Regression and progression of thrombus masses were sometimes observed side by side in the same leg.

This material includes a group of cases in which phlebographies were also carried out before the intervention. It was naturally not our intention to investigate whether such examinations have any value as a routine. Phlebographies are too time consuming examinations to be used routinely unless pressing medical reasons are at hand. Nonetheless, it was considered that a series of pre operative phlebographies might give valuable information. They established that it cannot be taken for granted that a thrombus demonstrated at postoperative phlebography really has arisen after the operation. They also helped to establish that the concept of total regression of a thrombus is a reality since in a number of cases with definitely established thrombosis phlebographies carried out a considerable time after the condition was diagnosed revealed that the vascular anatomy had resumed its original pre operative appearances.

- HAEGER K. Den kliniska trombosdiagnostikens (o) tillförlitlighet (In Swedish) Svenska Lak. Tidsn. 62 (1965), 1067
- and NYLANDER G. Acute phlebography. Triangle 8 (1967), 18
- HJELMSTEDT A and BERGMALL U. Incidence of thrombosis with tibial fractures. Acta chir scand. 134 (1968), 209
- LINDBOM A. Venographie. In: Lehrbuch der Röntgendiagnostik, p. 1815. Edited by H. R. Schintz. Georg Thieme Verlag, Stuttgart 1952
- MAY R and NISSEL R. Die Phlebographie der unteren Extremität. Georg Thieme Verlag, Stuttgart 1959
- NYLANDER G. Phlebographic diagnosis of acute deep leg thrombosis. Acta chir scand. Suppl. 287 (1968), 30
- ZACHRISSON B. (1968) Personal communication

with phlebography was investigated and the incidence, sites and phlebographic appearances of postoperative thrombosis are described and compared with the findings of other investigators

ZUSAMMENFASSUNG

Das Auftreten der Postoperativen Thrombose in den Beinen nach Prostataentfernung wurde phlebographisch an 367 unteren Extremitäten in 187 Fällen studiert. Die diagnostische Zuverlässigkeit der klinischen im Vergleich zu der phlebographischen Untersuchung wurde überprüft und das Vorkommen, der Sitz und die phlebographischen Symptome der Thrombose werden besprochen. Die Resultate werden mit denen anderer Autoren verglichen.

RÉSUMÉ

Les auteurs ont étudié la thrombose post opératoire après prostatectomie sur 519 phlebographies de 367 membres inférieure dans 187 cas. Ils ont comparé l'exactitude du diagnostic clinique à la phlebographie et ils décrivent la fréquence, le siège et les images phlebographiques de la thrombose post-opératoire et comparent leurs résultats avec ceux d'autres auteurs.

REFERENCES

- ALMÉN T and NYLANDER G. False signs of thrombosis in lower leg phlebography. *Acta radiol. Diagnosis* 2 (1964), 345.
- BAUER G. A venographic study of thrombo embolic problems. *Acta chir. scand.* (1940) Suppl. 61.
- BECKER J and BORGSTROM S. Incidence of thrombosis associated with epsilon aminocaproic acid administration and with combined epsilon aminocaproic acid and subcutaneous heparin therapy I. *Acta chir. scand.* 134 (1968) 343.
- and SALTZMAN G-F. Incidence of thrombosis associated with epsilon aminocaproic acid administration and with combined epsilon aminocaproic acid and subcutaneous heparin therapy II. To be published in *Acta chir. scand.*
- BERGVALL U and HJELMSTEDT Å. Recanalisation of deep venous thrombosis of the lower leg and thigh. *Acta chir. scand.* 134 (1968), 219.
- BORGSTROM S. Postoperative anticoagulant prophylaxis of venous thrombosis with dicoumarol. *Zbl. Phlebologie* 6 (1967) 30.
- GREITZ T, VAN DER LINDEN et coll. Ascending phlebography in fresh thrombosis of the lower limb. *Amer. J. Radiol.* 94 (1965) 207.
- FREEMAN R J, BOSWICK J and FARDIN R. Posttraumatic venous thrombosis. *Arch. Surg.* 95 (1967), 567.
- GREITZ T. Technique of ascending phlebography of lower extremity. *Acta radiol.* 42 (1954), 421.



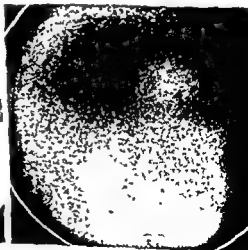
Fig 1 Lateral scintigram of left hemisphere
Multiple metastases (bronchogenic carcinoma)

1967, LOKEN, TELANDER & SALMON 1965, LOKEN, TELANDER & LAXDAL 1966, TELANDER & LOKEN 1967)

The expected differences might mainly be attributed to the different collimation. The gamma camera with its non-focussing collimator would probably give a better representation of superficial tumours, metastases and infarction, and at the same time a better representation of superficial extracerebral structures



a



b

Fig 2 Ap (a) and right lateral (b) scintigrams Glioblastoma of corpus callosum.

SCINTILLATION CAMERA AND RECTILINEAR SCANNER FOR DETECTION OF SPACE OCCUPYING INTRACRANIAL LESIONS

by

MOGENS PEDERSEN and JENS HAASE

Most authors have found no substantial difference in the diagnostic accuracy between the two most commonly used isotopes for brain scintillography, $^{99}\text{Tc}^m$ and ^{197}Hg chlormerodrin while in practice the prevailing circumstances may indicate the technetium isotope to be the one of choice. The short half life (6 hours) allows a high dose to be given without exceeding the permissible limits of radiation load. This high permissible dose ensures good counting statistics and shorter examination procedures.

The gamma scintillation camera (ANGER 1963) has found increasing application since 1965 in cerebral as well as in other scintillographic procedures. The disintegrations in the whole organ under study are recorded in one field of vision in contrast to the rectilinear scanning system which produces successive point by point recording of the disintegrations. In large organs like the brain this latter method is rather time consuming.

Only few studies have been undertaken to compare the clinical results of the two methods, those available being mostly phantom investigations (ANGER et coll

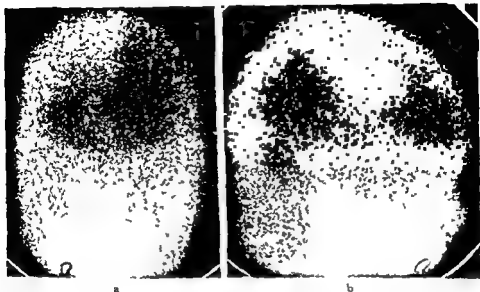


Fig 4 Ap (a) and right lateral (b) scintigrams. Arteriovenous malformation in right hemisphere.

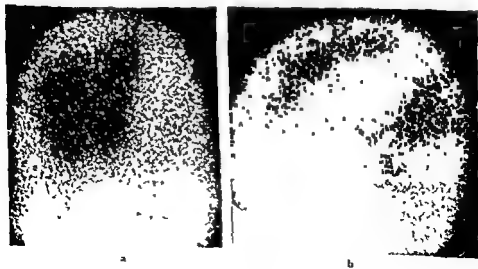


Fig 5 Ap (a) and left lateral (b) scintigrams. An 8 day old infarction in the left hemisphere.



Fig 3 Lateral scintigram of right hemisphere
Temporal lobe abscess

such as the temporal muscle and isotope concentrating processes in the cranial wall. The rectilinear scanner, on the other hand, which is equipped with a focussing collimator, would possess an advantage in that tumours in the focal plane of the collimator can be demonstrated, while at the same time a smoothing out effect on more superficial isotope concentrations would be produced.

All the brain scintillographies in our department from September 1968 to June 1969 were made with both the rectilinear scanner and the gamma camera with a view to investigate whether the fast working gamma camera yielded the same diagnostic accuracy as the rectilinear scanner.

Method Technetium 99m pertechnetate ($^{99m}\text{Tc}^m$) from a Philips/Duphar generator (molybdenum 99m ammonium molybdate absorbed in aluminium oxide) in a dose of 100 to 150 $\mu\text{Ci/kg}$, 8 to 15 mCi per study, was given intravenously. Rectilinear scanning was performed first and was started 20 minutes after the injection of the isotope. Depending on the duration of this examination, the gamma camera investigation followed 60 to 80 minutes after the injection. No potassium perchlorate or atropine was used.

The rectilinear scanner was a Picker Magna V, with a 5" NaI crystal and a 5" 85 hole focussing collimator, Picker 2011, collecting 8 000 to 12 000 counts per minute with a scanning speed of 100 to 110 cm/minute, background subtraction 10 to 25 %, total time per study 40 to 60 minutes. The scintigrams are presented in color script and photographic film in the magnitude 1:1.

The gamma camera was a Nuclear Chicago Pho/Gamma III equipped with a 11.5" \times 0.5" NaI crystal and a 4 000 hole non focussing collimator, collecting

Table 2

Scintillographic results obtained with gamma camera and rectilinear scanner in a group of patients with space-occupying cerebrovascular episodes

Nature of process	Days after episode	Number	Verified	Gamma camera			Scanner		
				++	+	0	++	+	0
Infarction	0-3	4	2	1	0	3	1	0	3
	4-7	9	9	3	1	5	5	2	2
	8-14	7	4	5	1	1	4	1	2
	15-21	3	3	2	1	0	2	1	0
	> 22	6	6	4	1	1	3	1	2
Hematoma		3	3	1	0	2	1	0	2
Total	Number	12	27	16	4	12	16	5	11
	Per cent	100	84	63	37		66	33	

Table 3

Scintillographic results obtained with gamma camera and rectilinear scanner in a group of patients with non malignant space occupying lesions

Nature of process	Number	Verified	Gamma camera			Scanner		
			++	+	0	++	+	0
Encephalitis	10	9	5	1	4	5	1	4
Meningocerebral cicatrix	1	1	1	0	0	1	0	0
Hygroma	1	1	1	0	0	1	0	0
Arachnoid cyst	2	2	0	0	2	0	1	1
Temporal lobe cyst	1	1	0	0	1	0	0	1
Temporal lobe abscess	1	1	1	0	0	1	0	0
Total	Number	16	8	1	7	8	2	6
	Per cent	100	94	56	44	62	38	

Results

Intracranial space-occupying lesions were detected in 105 (49%) of the 213 patients forming the series. Space occupying lesions include primary and secondary neoplasms, infarctions, encephalitis and intra- and extracerebral hematomas. The final diagnosis was made by operation, autopsy or neuroradiologic studies in 92 patients of the series and in a further 13 the diagnosis was established by the clinical course of the disease. Both supra- and infratentorial tumours were present in one patient.

Table 1

Scintillographic results obtained with gamma camera and rectilinear scanner in supra and infratentorial tumours

Nature of process	Number	Verified	Gamma camera			Scanner			
			++	+	0	++	+	0	
<i>Supratentorial</i>									
Glioma benign	7	7	3	0	4	3	1	3	
Glioma malignant	4	4	3	0	1	3	0	1	
Glioblastoma	13	13	13	0	0	13	0	0	
Meningioma	9	9	8	0	1	7	1	1	
Metastases	14	8	13	1	0	14	0	0	
Arteriovenous malformation	3	3	3	0	0	3	0	0	
Other tumours	3	3	2	0	1	0	1	2	
Total	Number	53	47	45	1	7	43	3	7
	Per cent	100	89	87	13		87		13
<i>Infratentorial</i>									
Acoustic neurinoma	2	2	1	0	1	1	0	1	
Metastases	2	1	2	0	0	2	0	0	
Pontine glioma	1	1	0	0	1	0	0	1	
Total	Number	5	4	3	0	2	3	0	2
	Per cent	100	80	60	40		60		40

100 000 counts per minute up to a total of 400 000 to 500 000 counts. The studies were performed using three or four projections, which required a total of 15 to 20 minutes per study. The results are presented in scintigrams of different intensity on 7 cm \times 9 cm polaroid film.

The examinations were performed by well-trained laboratory workers, as routine work under definite rules. The scintigrams were assessed by the authors together, without knowledge of the diagnosis or the clinical conditions of the patient.

Scintigrams with pathologic activity of an intensity equal to or greater than the activity of the frontal cranial wall were classed ++ positive, those of intensity less than that of the cranial wall but greater than the activity normally seen were classed + positive, while those with a low homogeneous activity over the cerebral hemispheres and the posterior fossa were recorded as negative.

The quality of the scintigrams was also judged as regards incorrect adjustment of instruments, distortion of projections and movement.

Table 2

Scintillographic results obtained with gamma camera and rectilinear scanner in a group of patients with space-occupying cerebrovascular episodes

Nature of process	Days after episode	Number	Verified	Gamma camera			Scanner		
				++	+	0	++	+	0
Infarction	0-3	4	2	1	0	3	1	0	3
	4-7	9	9	3	1	5	5	2	2
	8-14	7	4	5	1	1	4	1	2
	15-21	3	3	2	1	0	2	1	0
	> 22	6	6	4	1	1	3	1	2
Hematoma		3	3	1	0	2	1	0	2
Total	{	Number	32	16	4	12	16	5	11
		Per cent	100	63	37		66	33	

Table 3

Scintillographic results obtained with gamma camera and rectilinear scanner in a group of patients with non malignant space-occupying lesions

Nature of process	Number	Verified	Gamma camera			Scanner		
			++	+	0	++	+	0
Encephalitis	10	9	5	1	4	5	1	4
Meningocerebral cicatrix	1	1	1	0	0	1	0	0
Hygroma	1	1	1	0	0	1	0	0
Arachnoid cyst	2	2	0	0	2	0	1	1
Temporal lobe cyst	1	1	0	0	1	0	0	1
Temporal lobe abscess	1	1	1	0	0	1	0	0
Total	{	Number	16	15	7	8	2	6
		Per cent	100	94	56	44	62	38

Results

Intracranial space-occupying lesions were detected in 105 (49%) of the 213 patients forming the series. Space-occupying lesions include primary and secondary neoplasms, infarctions, encephalitis and intra- and extracerebral hematomas. The final diagnosis was made by operation, autopsy or neuroradiologic studies in 92 patients of the series and in a further 13 the diagnosis was established by the clinical course of the disease. Both supra- and infratentorial tumours were present in one patient.

Table 4

Scintillographic results obtained with gamma camera and rectilinear scanner in a group of patients with other intracranial lesions than space occupying

Nature of process	Number	Verified	Gamma camera			Scanner			
			++	+	0	++	+	0	
Arteriosclerotic encephalopathy	24	22	2	0	22	2	2	20	
Hypertensive encephalopathy	4	2	0	2	2	0	2	2	
Transitory cerebral ischaemia	7	4	0	0	7	0	0	7	
Non tumorous epileptic disorders	26	24	0	2	24	1	2	23	
Migraine	14	5	1	1	12	0	1	13	
Paralysis agitans	5	2	0	0	5	0	0	5	
Neurosis	7	4	1	1	5	0	0	7	
Others	21	11	2	1	18	2	4	15	
Total	Number	108	74	6	7	95	5	11	92
	Per cent	100	69	12	88	15		85	

Table 5

Positive scintigrams obtained in a group of patients with other intracranial lesions than space occupying

Nature of process	Gamma camera		Scanner	
	++	+	++	+
Choroid plexus	2	2	2	3
Cranial wall metastases	2	0	2	0
Soft tissue trauma	1	0	0	0
Mucocoele in frontal sinus	0	1	0	1
Sequela \acute{e} s from craniotomy	0	0	0	1
'False positive'	1	4	1	6
Total	6	7	5	11

For the whole group of space-occupying lesions (Tables 1, 2 and 3) the positive scintigrams were 78 (73.5%) and 75 (70.5%) respectively from the gamma camera and the scanner while in the group of supra- and infratentorial tumours (Table 1) 80% positive scintigrams were obtained, this group includes tumours of all grades of malignancy.

As regards the results of scintillography in supratentorial tumours (Table 1) it may be observed that a small flat suprasellar meningioma escaped detection both by the gamma camera and the scanner but the high diagnostic accuracy for glioblastomas, meningiomas and metastases is notable.

Table 6

Analysis of the technical quality of scintigrams obtained with respectively gamma camera and rectilinear scanner

Characterization	Gamma camera	Scanner
Unsatisfactory	0	8
Movement	3	22
Oblique	3	9
Wrong projection	1	2
Instrumentation	0	6
Total {Unsatisfactory	0 (0 %)	8 (4 %)
Just acceptable	7 (3 %)	39 (18 %)

Table 7

Comparison of the qualities of the positive (++) scintigrams obtained with the gamma camera as well as the rectilinear scanner

Nature of process	Number	Camera better	Scanner better	Equally good
Glioma benign	3	2	0	1
Glioma malignant	3	1	1	1
Glioblastoma	13	6	1	6
Meningioma	7	1	1	5
Metastases	13	5	1	9
Arteriovenous malformation	3	2	0	1
Infarction	12	5	1	6
Intracerebral hematoma	1	0	0	1
Encephalitis	5	3	2	0
Other supratentorial space occupying lesions	4	1	1	2
Infratentorial tumours	3	0	1	2
Total {Number	67	24	9	34
Per cent	100	36	13	51

Scintillographic demonstration of tumours of the posterior fossa is known to be difficult, especially with $^{99}\text{Tc}^m$ because of the high concentration of the isotope in the tissues overlying this area. The present series of patients included only five with such tumours, two with metastases and two with an acoustic neuroma. The pontine glioma and one of the neuromas were not diagnosed by the gamma camera nor by the scanner.

Cerebrovascular episodes are according to most authors (GLASGOW et coll

1967, MOLINARI et coll 1967) best demonstrated by scintillography 7 to 14 days following their occurrence. This was only partly confirmed by the present investigation (Table 2). The discrepancy in the results of scintillography by the two methods obtained from 4 to 7 days after a cerebrovascular episode, where the scanner seemed to give the best results, may be explained by the earlier mentioned assumption that the gamma camera over-emphasizes superficial activity and consequently hides underlying pathologic activity of low intensity.

Among the non-malignant, space-occupying lesions the group 'encephalitis' deserves special attention (Table 3). Marked scintillographic abnormalities, comparable to those seen in malignant tumours, were present in five out of ten patients and in a further patient less prominent but still abnormal changes were recorded. A large arachnoid cyst in the fissura Sylvii was faintly demonstrated by the scanner but was missed by the gamma camera.

In the inhomogeneous group of patients without space-occupying lesions (Table 4) 74 diagnoses out of 108 (67 %) were verified by operation, autopsy or neuroradiologic studies, in this group 13 and 16 abnormal scintigrams were obtained respectively by the gamma camera and the scanner. Five of these were due to two metastases to the cranial wall, one traumatic lesion, one mucocoele and one from postoperative sequelae, while four and five, respectively, on revision turned out to be due to a misinterpreted plexus choroideus. This left five and seven, respectively, as false positives (Table 5).

The technical qualities of the scintigrams are compared in Table 6. The gamma camera scintigrams were never without value while rectilinear scanning in eight instances gave completely unsatisfactory results. If the patient moves this is a difficult problem in rectilinear scanning but hardly any problem with the faster gamma camera.

Sixty-seven scintigrams which with both examination methods were ++ positive formed the basis on which to select the better method of demonstrating a lesion (Table 7). The representation was equally good in half the number of patients while the gamma camera provided the better demarcation of the lesion in 36 % of the patients.

Discussion and Conclusion

The results usually reported in cerebral scintillography using $^{99}\text{Tc}^m$ appear to be more or less confirmed. Apart from the apparently better demonstration of infarction by rectilinear scanning in the period 4 to 7 days after a cerebral episode, no essential differences in diagnostic accuracy were observed between the two methods. In no instance did the scanner reveal a neoplasm that was not equally well, or even better, demonstrated by the gamma camera. We feel that

the gamma camera often provides a sharper representation of pathologic changes, especially in cases of infarction. Furthermore, although not definitely confirmed in the present series of patients, the camera appears to be more satisfactory for the posterior fossa than the rectilinear scanning system with $^{99}\text{Tc}^m$.

The practical advantages of the gamma camera are obvious. Much shorter time is required for each examination, an important point in view of the fact that the patients are often seriously ill and uncooperative. Gamma camera scintillography appears to be little susceptible to movement. The mini size of the gamma camera films at first sight appears to constitute a disadvantage and a solution to this problem could be to enlarge the scintigrams. In our opinion a better method is however to use the gamma camera study as a screening procedure, which we have done since the termination of the present investigation. After screening, the lesion is scanned conventionally from the relevant side, using a suitable projection, if possible with the focal plane of the detector at the level of the pathologic process. The conditions for the production of a full size scintigram then become ideal.

SUMMARY

Two hundred and thirteen patients were investigated with a gamma camera and a rectilinear scanner for tumours and other intracranial conditions. No essential differences between the two methods as regards diagnostic accuracy were apparent although the gamma camera appeared to possess considerable practical advantages.

ZUSAMMENFASSUNG

Zweihundertdreizehn Patienten mit Gehirntumoren und anderen intrakraniellen Läsionen wurden mit Gammakamera und geradliniger Szintigraphie untersucht. Keine wichtigen Unterschiede wurden hinsichtlich der diagnostischen Zuverlässigkeit zwischen den beiden Methoden beobachtet; die Gammakamera erwies sich jedoch als praktischer im Gebrauch.

RÉSUMÉ

Deux cent treize malades atteints de tumeurs ou d'autres affections intra-craniennes ont été examinés au moyen d'une gamma-camera et d'une scintigraphie rectiligne. Les auteurs n'ont pas constaté de différences essentielles entre ces deux méthodes en ce qui concerne la précision du diagnostic mais la gamma-caméra présente des avantages pratiques considérables.

REFERENCES

- ANGER H. O. Gamma ray and positron scintillation camera. *Nucleonics* 21 (1963), 56.
 — COLLIKA C. J., ROBINSON Th. and HAYT D. B. Comparative study of the gamma camera and rectilinear scanner. *Amer. J. Roentgenol.* 100 (1967), 761.
 GLASGOW J. L., CURRIER R. D., GOODRICH J. K. and TOROR F. T. Brain scans of cerebral infarcts with radioactive mercury. *Radiology* 88 (1967), 1086.

- LOKEN M K, TELANDER G T and LAXDAL S : Conventional scanning versus scintillation camera *Minn Med* 49 (1966), 237
- — and SALMON R J : Technetium 99m compounds for visualisation of body organs *J Amer med Ass* 194 (1965) 132
- WIGDAHL L O, GILSON J M and STAAB E V : Mercury 197 and mercury 203 chloromerodrin for evaluation of brain lesions using a rectilinear scanner and scintillation camera *J nucl Med* 7 (1966), 209
- McAFFEE J G and TANDAL D R : Comparison of radioisotope scanning with cerebral angiography and air studies in brain tumor localisation *Radiology* 77 (1961) 207
- MCCREADY V R and FIELD E O : Clinical use of the gamma camera *Biomed Engng* 3 (1968), 514
- MOLINARI G F, FIRCHER F and HEYMAN A : Serial brain scanning using technetium 99m in patients with cerebral infarction *Neurology* 17 (1967) 627
- PAULSON O H, BJERRUM J K og LAHRENKRUG A : Hjernescanning med radioaktive isotoper (In Danish) *Ugeskr Læg* 131 (1969) 1043
- QUINN J L, CIRIG I and HALSER W N : Analysis of 96 abnormal brain scans using technetium 99m (pertechnetate form) *J Amer med Ass* 194 (1965) 137
- RHOTOV A L, EICHLING J and TER POGOSSIAN M M : Comparative study of mercury 197 chloromerodrin and mercury 203 chloromerodrin for brain scanning *J nucl Med* 7 (1966) 50
- SCHLESINGER E B, DE BOVES S and TAVERAS J : Localisation of brain tumors using radioiodinated human serum albumin *Amer J Roentgenol* 87 (1962) 449
- SCHNEIDER C, PREVOT H and TZOVOS T : Szintigraphie mit ^{203}Hg und ^{99}Tc in der Diagnostik von Hirntumoren *Dtsch med Wschr* 93 (1968) 285
- TELANDER G T and LOKEN M K : Comparison of the scintillation camera with a conventional rectilinear scanner using technetium 99m pertechnetate in a tumor brain phantom *J nucl Med* 8 (1967) 481
- WEBBER M M : Technetium 99m normal brain scans and their anatomic features *Amer J Roentgenol* 94 (1965) 815
- WITCOWSKI R L, MAYNARD C D and ROPER T J : A comparative analysis of the accuracy of the technetium 99m pertechnetate brain scan. Follow up of 1 000 patients *J nucl Med* 8 (1967), 187

ROENTGEN EXAMINATION OF THE FACIAL CANAL

by

S BRUNNER and CHR BRAHE PEDERSEN

Tomography of the temporal bone usually proves of considerable value in the investigation of facial palsy. The method enables the detail of the bone, including its osseous walls, to be examined. Advances in otosurgery have provided a new approach for treatment of facial palsy, and the exact localization of the site of a pathologic process in the temporal bone has become an essential pre-operation requisite.

Anatomy: The facial, or seventh cranial, nerve passes through a long osseous canal, the facial canal, shortly after leaving the pons. The facial canal, 5 cm in length, is divided into three parts (Fig. 1). The first part stretches from the internal auditory meatus to the geniculate ganglion, it is about 1.5 cm long and most of the way lies just above the accompanying acoustic nerve. The facial nerve performs a 100 degree bend in the medial wall of the tympanic cavity above the cochlea and vestibular window and below the lateral semicircular canal. A second bend occurs at the pyramidal eminence. The third part of the facial canal runs inferovertically and is about 1.5 cm in length. The canal then opens out at the base of the skull into the stylomastoid foramen. The course now described is the normal one.

Submitted for publication 9 December 1969



Fig 1 Anatomy of the facial canal modified after SHAMBAUGH. Geniculate ganglion and first bend (1), second bend (2), third part of canal (3), stylomastoid foramen (4), vestibular window (5), semicircular canal (6), cochlea (7), carotid canal (8), incus (I), and malleus (M).

Atypical courses of the facial nerve have sometimes been described (KETTEL 1963) and are of considerable surgical importance. The nerve in its intraosseous course sends several fibres to the salivary and lacrimal glands and to the taste buds, and innervates the stapedius muscle. Examinations of these nerve functions make a topographic diagnosis in lesions of the facial nerve possible (SHAMBAUGH 1967). The nerve is abundantly supplied with blood, each part from at least two sources. The canal is so wide that the nerve only occupies 50 to 70 per cent of its volume.

Tomographic representation. The facial canal may be demonstrated in its full length by tomography of the temporal bone with 1 mm between the cuts. The best projections for a correct assessment of the canal are a p and lateral projections, supplemented by a half-axial projection (BRUNNER et coll 1961, VALVASORI 1963).

To provide an accurate concept of the roentgen anatomy, a wire was placed in the facial canal of a phantom. The first and second horizontal parts of the canal are depicted in Fig 2, representing an a p tomographic cut in the cochlear plane, in which the facial canal appears as two foramina just above the cochlea. The



Fig 2 Ap tomography of a phantom at level of cochlea. Facial canal appears as two foramina just above the cochlea (3)



Fig 3 Ap tomography 2 mm more posteriorly than in fig 2. Second bend (1), mastoid part (2), and petrous part (3), of the facial canal



Fig 4 Lateral tomography of a phantom at level of the facial canal. Second bend (1), and vertical or mastoid parts (2), of the canal

medial of these is the end of the first part of the facial canal which contains the geniculate ganglion and is often a little wider. The lateral 'hole' constitutes the beginning of the second part of the facial canal.

A cut a few millimeters more posteriorly (Fig 3) demonstrates the position of the facial canal in relation to the vestibular window, the canal being situated just above the latter and just below the lateral semicircular canal. A lateral tomogram demonstrates the anatomical conditions of the canal placed deep in the mastoid process as it continues its vertical course (Fig 4).

The normal roentgenologic appearances are presented in Fig 5, which is an ap tomographic cut in the cochlear plane. A spiral shaped cochlea lies in the centre, with the canal represented by two 'holes' proximal to the cochlea. The lateral of these, containing the second part of the canal, is often represented more as a pit than a hole. The second bend and the vertical course of the canal to the stylomastoid foramen is usually well demonstrated by lateral tomography (BRUNNER 1969) (Fig 6).

The causes of facial palsy may be divided into (1) diseases of the central nervous system, (2) local conditions, (3) systemic diseases, with or without peripheral neuropathy, and (4) unknown etiology. Roentgenologic changes in the facial canal, as in other situations, may be caused by trauma, inflammation, or neoplasms.

Fractures of the temporal bone may be divided into longitudinal and transverse, a combination seldom occurs.

Longitudinal fractures are the more frequent ones. The symptoms and signs are bleeding from the ear, hematotympanum and rupture of the tympanic

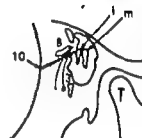


Fig 5 Ap tomography at level of cochlea of a normal right ear. The lateral meatus is produced by the tympanic segment of the canal (1) the medial hole is larger because it contains the geniculate ganglion and the petrous segment of the facial nerve (2) cochlea (3) malleus (4)

Fig 6 Lateral tomography at the level of the facial canal of a normal left ear. Second bend of facial canal (1) mastoid course of facial canal (2) malleus (m) in cus (i) and the temporomandibular joint (T)

Fig 7 Lateral tomography in a female with right facial palsy after a traffic accident 2 weeks earlier. Fracture (arrows 10) involves the facial canal near the second bend in its mastoid part (3) incus (i) malleus (m) and temporomandibular joint (T)

membrane (PETERSEN 1961). The facial nerve is involved in about 25% of cases, the vertical part of the canal and the region of the second bend are most often affected (Fig 7). Facial palsy is usually of the delayed type, presumably due to swelling, bleeding or ischemia. Treated conservatively the prognosis is fair.

In transverse fractures, hemi-otympanum also occurs, but bleeding from the ear and rupture of the eardrum are unusual. Transverse fractures are in 50% of cases followed by facial palsy. The fractures often involve the cochlea or the capsule of the labyrinth, causing total deafness in the same way as a fracture of the first part of the facial canal because of its site close to the acoustic nerve. The palsy is of the immediate type and the prospects of spontaneous remission are poor.

The cessation of facial function in direct relationship to the trauma or the appearance of facial palsy within a few days are clinically important. In the first

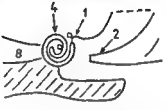
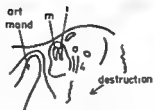
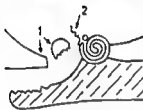


Fig 8 A-p tomography in a female aged 51 with right chronic otitis media for many years and right peripheral facial palsy for 3 months. Destruction of the spur of the lateral wall of attic (1) and handle of the malleus as well as of the medial wall of the attic around the facial canal (2). Squamous cell carcinoma.

Fig 9 Lateral tomography in a female aged 61 who 2 years earlier was operated upon for a left parotid tumour, left peripheral facial palsy for 6 weeks. Destruction of the mastoid extending into and around the third part of facial canal (arrow) malleus (m) incus (i) the facial canal (4).

Fig 10 A-p tomography in the cochlear plane of male aged 45, with left chronic otitis media complicated by cholesteatoma left peripheral facial palsy for one week. Destruction of the lateral wall of the attic and the spur (2) as well as of the medial wall of the attic containing the second part of the facial canal (1), the cochlea (4).

case operation is definitely indicated while in the second the prognosis is relatively good without treatment. It may prove difficult to decide whether the facial palsy in an unconscious patient is acute or delayed.

Another kind of lesion of the facial canal is one produced by the iatrogenetic factor of ear operations. According to KOERNER, an earlier investigation has revealed lesions of the facial nerve in 37% of all otosurgical operations. With improved operation techniques, the incidence of facial complications in primarily operated ears is in the next days probably about 1%, while facial lesions may occur in about 10% of re-operations.

Tumours The facial nerve may be affected by benign or malignant growths. The benign tumours consist mostly of neurinomas, these usually arise from the acoustic nerve — which in the first part of the facial canal is closely related to the facial nerve — and involve the facial nerve indirectly (VALVASSORI 1969).

Primary malignant neoplasms are generally represented by squamous cell

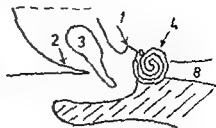


Fig. 11 A p tomography in the cochlear plane of male, aged 49, with right chronic otitis media of 6 years and facial palsy of 5 days duration. Destruction around the second part of facial canal (1) and blurring of the attic. Normal lateral wall and spur (2), malleus (3) and cochlea (4).

carcinoma, seldom by sarcoma, which arise in the external auditory canal or in the middle ear, erode the facial canal and affect the facial nerve (Fig. 8). Secondary growths — such as from parotid tumours (Fig. 9) or rhinopharyngeal carcinoma spreading into the surrounding tissue — may likewise result in destruction of the facial nerve. Metastases from primary carcinoma of the mammae or lungs may, if located in the temporal bone, involve the nerve. Metastases from the gastro-intestinal tract are of course rarely encountered in this region.

Infection. Meningitis, tuberculosis, syphilis, herpes zoster and infectious mononucleosis, and so forth, may produce facial paralysis. Cessation of function of the facial nerve most frequently occurs after chronic otitis media or cholesteatomatous otitis. Acute otitis media may also result in facial palsy produced by reactive edema. It is important in chronic otitis media to determine whether a cholesteatoma is present or not, the typical roentgenologic characteristics being destruction of the 'spur', ossicles and the smooth-walled cavity of the antrum (BRUNNER 1969). Continuation of the growth may result in a destruction of the osseous wall of the facial canal, followed by palsy caused by pressure or infection of the nerve (Fig. 10). Destruction of the osseous walls of the facial canal also occurs in chronic otitis media though usually only of the medial wall of the tympanic cavity, the 'spur' and the ossicle remaining intact (Fig. 11).

Discussion

Facial palsy is not uncommon. An etiologic explanation of its origin must always be sought in every case, as it is upon this that the course depends. It is always important to determine whether the paralysis has been caused by a reactive

nerve block or if the nerve fibres have degenerated, which means that confirmation is dependent on the regeneration of the latter. A close clinical examination may indicate a *prognosis of spontaneous remission* but this alone is not enough for establishing whether the case will improve or not. The nerve excitability test, in which the smallest electric current necessary for making a muscle contract is measured, is of considerable value, particularly when considering an operation (JONGKEES 1969).

Tomography of the facial canal may prove another valuable help in evaluating the chances of spontaneous healing by suggesting the basic disease leading to the facial paralysis.

JONGKEES (1965) mentioned that the use of tomography made it possible to demonstrate the exact position of a fracture in 21 out of 25 cases. Tomography, together with clinical considerations, may indicate an operation of decompression.

Tomography will enable the extension, localization and complication of a cholesteatoma of the middle ear to be assessed. This may sometimes make it possible to determine whether the facial palsy has been brought on by a chronic middle ear operation with destruction of the facial canal, or has just been caused by reactive edema. In the first instance the pressure on the canal will be relieved by the removal of granulations by open operation.

Normal tomography in a patient with facial palsy must obviously exclude a number of possible causes and will in itself prove a valuable aid.

Conclusion

Tomography of the facial canal is a valuable supplement to other examinations in the investigation of facial palsy. Traumatic changes, tumours or inflammatory changes in or about the canal will often be accurately diagnosed and the method must be regarded as secondary only to the clinical evaluation.

SUMMARY

The anatomy of the facial canal is described in some detail and the role of tomography of the temporal bone in the diagnosis of inflammation, fractures and neoplasms as causes of facial palsy is discussed. It is emphasized that tomography is an essential examination in this not uncommon condition.

ZUSAMMENFASSUNG

Die Anatomie des Gesichtskanals wird detailliert beschrieben und der Wert der Tomographie bei der Diagnose von Entzündungen, Frakturen und Neoplasmen als Ursachen der Gesichtslähmung wird diskutiert. Es wird betont, dass die Tomographie eine wesentliche Untersuchung bei dieser nicht seltenen Erkrankung ist.

RÉSUMÉ

Les auteurs décrivent de façon assez détaillée l'anatomie du canal facial et examinent le rôle de la tomographie du rocher dans le diagnostic de la cause inflammatoire traumatique ou néoplasique de la paralysie faciale. Ils insistent sur l'intérêt essentiel de la tomographie dans cette affection qui n'est pas exceptionnelle.

REFERENCES

- BRUNNER S. Roentgen anatomy of the temporal bone using the Polytome. *Semin Roentgenol* 4 (1969), 118.
- Infection of the temporal bone and its complications, including cholesteatoma. *Semin Roentgenol* 4 (1969), 129.
- and SANDBERG L. E. Tomography in the differential diagnosis of cholesteatoma and simple chronic otitis. *Arch Otolaryng* 91 (1970), 560.
- PETERSEN O. and STORSTED P. Laminagraphy of the temporal bone. *Amer J Roentgenol* 86 (1961), 281.
- — — Tomography of the facial canal in non rheumatic facial palsy. *Acta radiol. Diagnostis* 1 (1963), 90.
- JONGKEES L. B. W. Facial paralysis complicating skull trauma. *Arch Otolaryng* 81 (1965), 518.
- Tests for facial nerve function. *Arch Otolaryng* 89 (1969), 127.
- KETTEL H. Surgery of the facial nerve. *Arch Otolaryng* 77 (1963), 327.
- KOERNER O. Quoted by MIEHLKE A.
- MIEHLKE A. Typical sites of facial nerve lesions. *Arch Otolaryng* 89 (1969), 122.
- PETERSEN O. Transverse fracture of the petrous bone. *Arch Otolaryng* 73 (1961), 644.
- SHAMBAUGH JR G. E. Surgery of the ear. W. B. Saunders Philadelphia 1967.
- VALVASSORI G. E. Laminagraphy of the ear. Normal roentgenographic anatomy. *Amer J Roentgenol* 89 (1963), 1155.
- (1969) Personal communication.

CANNULA FOR INJECTION OF CONTRAST MEDIUM IN CEREBRAL ANGIOGRAPHY

by

GUNNAR WESTBERG

Cerebral angiography is now often performed by means of a catheter passed through the femoral artery. The need for angiographic examinations by direct puncture of the carotid artery will however always exist.

Direct puncture with a needle and the Seldinger method of an indwelling catheter are both connected with certain disadvantages. Plastic catheters threaded on a needle have long been in use for puncture of the liver and spleen. SOILA (1963) described a similar method for 'introduction of a soft cannula into the carotid artery by direct percutaneous puncture'. This was a step in the right direction but it would appear that the Soila catheter of teflon is too stiff and likely to cause intimal damage as it is pushed up through the vascular lumen. SOILA furthermore, recommended the use of an inner needle, 1 cm longer than the catheter threaded on it. This however tends to increase the difficulty of introduction rather than otherwise, as the needle has to be passed a considerable distance into the artery before the catheter can be pushed off the needle into the vessel.

There is thus a need for an improved instrument for direct puncture of the

Submitted for publication 31 January 1970

RÉSUMÉ

Les auteurs décrivent de façon assez détaillée l'anatomie du canal facial et examinent le rôle de la tomographie du rocher dans le diagnostic de la cause inflammatoire, traumatique ou néoplasique de la paralysie faciale. Ils insistent sur l'intérêt essentiel de la tomographie dans cette affection qui n'est pas exceptionnelle.

REFERENCES

- BRUNNER S. Roentgen anatomy of the temporal bone using the Polytome. *Semin Roentgenol* 4 (1969), 118
- Infection of the temporal bone and its complications, including cholesteatoma. *Semin Roentgenol* 4 (1969), 129
- and SANDBERG L. E. Tomography in the differential diagnosis of cholesteatoma and simple chronic otitis. *Arch Otolaryng* 91 (1970), 560
- PETERSEN O. and STOKSTED P. Laminagraphy of the temporal bone. *Amer J Roentgenol* 86 (1961), 281
- — Tomography of the facial canal in non rheumatic facial palsy. *Acta radiol. Diagnosis* 1 (1963), 90
- JONGKEES L. B. W. Facial paralysis complicating skull trauma. *Arch Otolaryng* 81 (1965), 518
- Tests for facial nerve function. *Arch Otolaryng* 89 (1969), 127
- KETTEL K. Surgery of the facial nerve. *Arch Otolaryng* 77 (1963), 327
- KOERNER O. Quoted by MIEHLKE A.
- MIEHLKE A. Typical sites of facial nerve lesions. *Arch Otolaryng* 89 (1969), 122
- PETERSEN O. Transverse fracture of the petrous bone. *Arch Otolaryng* 73 (1961), 644
- SHAMBAUGH JR G. E. Surgery of the ear. W. B. Saunders Philadelphia 1967
- VALASSORI G. E. Laminagraphy of the ear. Normal roentgenographic anatomy. *Amer J Roentgenol* 89 (1963), 1155
- (1969) Personal communication

cannula is softer than teflon although sufficiently stiff to enable it to be passed up into a blood vessel, without the aid of a guide, if the angle of puncture is not too steep, an angle of 45° , or a little less, is suitable. The needle tip has a bevel of 30° . The outer cannula has an external diameter of 1.60 mm and an internal diameter of 1.14 mm. The stylet has an inner diameter of 0.7 mm and its length is 10 cm. The tip of the outer cannula reaches to the eye of the stylet (Fig. 2).

Prior to puncture, a hole should be made in the skin with a larger needle or a scalpel. If this is not done, there is a risk that the catheter tip may be deformed as it passes through more or less tough skin. After the artery has been punctured, the outer cannula is advanced over the stylet and pushed into the blood vessel for a distance of one or two centimeters before the stylet is withdrawn. This ensures that the cannula does not slip out (Fig. 3). If there is any uncertainty regarding the position of the needle, a check can be made by injecting contrast medium through the stylet before the outer cannula is removed. The stylet having been withdrawn, it should not be reinserted while the outer cannula is still in position, as there then would be a considerable risk that it might perforate the cannula. The resistance to injection is low in the outer cannula, much less than in a metal needle of the same caliber.

The instrumentarium forms part of a series that can be built up with the aid of Luer couplings and includes units with stopcocks, side holes, and other elements. A middle piece consists of transparent tubing that can be compressed with artery forceps or other types of clamp. A special tap, if considered necessary, can readily be fitted to the middle piece.

This system has been in use for over a year and has proved highly advantageous. The value of having a soft plastic tube in the artery instead of a metal needle is obvious, especially when the patient is likely to be restless or when alterations in the positioning of the head for different projections may endanger the correct position of the needle. The equipment has also proved useful for retrograde injection of contrast medium into the brachial artery for vertebral angiography.

The equipment is supplied in an expendable pack by AB Stille-Werner, Stockholm, under the name Stille Contrast Injection Cannula.

SUMMARY

Equipment for direct puncture of the carotid artery, consisting of a modification of the Stille infusion cannula, is described. The cannula has been on trial for more than a year and its value has been proved.

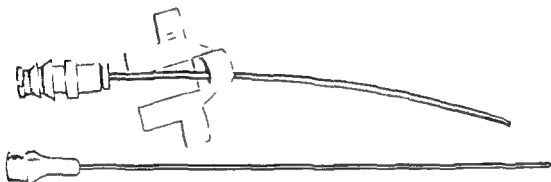


Fig 1 The assembled puncture instrument is shown at the top and the separate parts below

Fig 2 The tip of the outer cannula reaches to the eye of the stylet



Fig 3 The outer cannula is introduced a certain distance before removal of the stylet

carotid artery. The Stille infusion cannula, which has been on the market for some time, has been modified and appears to offer many advantages (Fig 1).

The instrumentarium consists of an inner stylet of flexible steel wire and an outer cannula of polythene, both in a sterile pack. The wire stylet, before its removal from the pack, can without difficulty be shaped as desired. The outer

A SAFER ENEMA NOZZLE

by

OVE MATSSON

The examination of the colon by means of a barium enema is a frequent roentgen procedure, generally considered to be without risk. The anatomic deviation of the rectum dorsally against the sacrum favours however lesions in the ventral rectal wall. If the tip of the nozzle of the enema tube is pressed tightly against the rectal wall, local pressure increase may result (Fig. 1, an arrow indicates the opening in the tip). Perforation of the mucous membrane will then make injection of the contrast medium into the soft tissues a possibility, with dire results.

Several cases of serious injury to the rectum in connection with enemas are reported in the literature. In 1937 GALBRAITH described trauma caused by the use of a rigid enema nozzle. BALLOU & GOLDBLOW (1941) reported the effects caused by incorrectly administered enemas. BOMAN *et coll.* (1952) described massive fatal embolism during a barium enema examination probably caused by a fissure or varix permitting the medium to enter the venous system. COOPER JR (1953) described the rectal tube as a lethal instrument. Similar fatal cases have occurred in Sweden during the last two decades although they have not been published.

Any injury of the rectal wall made by a thermometer or cleansing enema before or at the beginning of the examination may thus produce contrast filling of the

ZUSAMMENFASSUNG

Ein Gerät zur direkten Punktion der Arteria carotis, das aus einer Modifikation der Stille Infusionskanüle besteht, wird beschrieben. Die Kanüle hat sich in einer einjährigen Probezeit gut bewährt.

RÉSUMÉ

L'auteur décrit l'appareillage de perfusion de Stille appliqué à la ponction directe de l'artère carotide. Un essai de plus d'un an a montré l'intérêt de ce trocart.

REFERENCE

SOILA P. Introduction of a soft cannula into the carotid artery by direct percutaneous puncture. *Acta radiol. Diagnosis* 1 (1963), 451.

A SAFER ENEMA NOZZLE

by

OVE MATTSÖN

The examination of the colon by means of a barium enema is a frequent roentgen procedure, generally considered to be without risk. The anatomic deviation of the rectum dorsally against the sacrum favours however lesions in the ventral rectal wall. If the tip of the nozzle of the enema tube is pressed tightly against the rectal wall, local pressure increase may result (Fig. 1, an arrow indicates the opening in the tip). Perforation of the mucous membrane will then make injection of the contrast medium into the soft tissues a possibility, with dire results.

Several cases of serious injury to the rectum in connection with enemas are reported in the literature. In 1937 GALBRAITH described trauma caused by the use of a rigid enema nozzle. BALLOU & GOLDBLOM (1941) reported the effects caused by incorrectly administered enemas. BOMAN *et coll.* (1952) described massive fatal embolism during a barium enema examination probably caused by a fissure or varix permitting the medium to enter the venous system. COOPER JR (1953) described the rectal tube as a lethal instrument. Similar fatal cases have occurred in Sweden during the last two decades although they have not been published.

Any injury of the rectal wall made by a thermometer or cleansing enema before or at the beginning of the examination may thus produce contrast filling of the

Submitted for publication 2 June 1969



Fig 1 The single opening (arrow) of a conventional enema nozzle is often pressed against the rectal wall during insertion

veins. As soon as a sealed communication between the tip and the perforated mucous membrane exists, such a situation may arise. At double-contrast examinations air may also be insufflated into the intestinal wall in cases of defects in the wall.

The present conventional design of catheter tips with a single outlet favours the effect described — local pressure increase built up by close contact between the opening of the tip and the intestinal wall. Thin hard tube-like enema nozzles with sharp edges that may readily damage the mucous membrane are also in use. Nozzles with a rounded end and a single outlet, the diameter of a lead pencil, are often employed, these may produce dangerous effect.

The main principle of the new catheter is a tip with a multiple opening. The risk of occlusion and pressure increase are thus practically eliminated, the risk of



Fig 2 An early model (1955) of a nozzle with a multiple opening

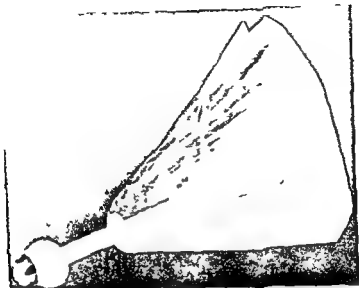


Fig 3 The new disposable enema nozzle with multiple small holes. A thin plastic collar protects the hands of the operator and decreases the possibility of spread of bacteria from the rectum

obstruction of all openings by soft tissues must obviously be remote. In 1955 the author constructed an enema tip which had a few holes around its pear shaped end and was made of bakelite laminate (Fig 2). It aroused little interest. A disposable cheap single-opening nozzle was marketed some years later and has been much used. Two accidents that might be referred to the single opening principle have recently occurred in Sweden.

The new enema tip is made of polythene. The design of the tip as well as the location of the holes are paramount — the safety lies in the distribution of the openings around the periphery of the end, the whole is streamlined to facilitate application and function as well as to eliminate any risk of mechanical injury. The nozzle, which is disposable, is shown in Fig 3. A thin plastic collar protects the hands of the operator during its handling. To avoid the tip being introduced too far into the rectum a round plate, visible through the plastic collar, is located on the tube part.

Safe enema nozzles are essential for every kind of wash out enemas prior to colon examination, or roentgen diagnostic enemas. The present instrument appears to constitute an advance.

Acknowledgement

The construction has been developed in cooperation with Bertil Carlsson, Medical Plastic Equipment

SUMMARY

A new multiple opening tip for a barium enema nozzle is described. It is claimed to be safer than those normally in use.

ZUSAMMENFASSUNG

Eine neue Kanüle für den Bariumeinlauf mit mehreren Öffnungen wird beschrieben. Sie scheint zuverlässiger als die bisher benutzten Kanülen zu sein.

RÉSUMÉ

Description d'une nouvelle canule pour lavement baryte dont l'extrémité comporte plusieurs orifices. Son emploi paraît moins dangereux que celui des canules utilisées habituellement.

REFERENCES

- BALION H. C. and GOLDBLOW A. Serious injury to rectum from improperly administered enemas. *Canad. med. Ass. J.* 45 (1941), 345.
- BOMAN P. W., WAGNER J. H. and STLINBACH S. H. Massive fatal embolism during barium enema examination. *Radiology* 59 (1952), 190.
- BROWN S. and LINE A. Diffuse emphysema following double contrast enema. *Radiology* 37 (1941), 228.
- COOPER JR. W. C. Rectal tube as lethal instrument. *Amer. Surg.* 19 (1953), 270.
- GALBRAITH W. W. Severe rectal injuries caused by enema given through rigid nozzle. *Brit. med. J.* 1 (1937), 859.

Subject index to Volume 10 — Diagnosis

ROENTGEN DIAGNOSIS

Nervous system

Normal size of the internal carotid middle and anterior cerebral arteries	1
Skull size and ventricular dilatation in subdural hygroma in infants	11
Neurotoxicity of roentgen contrast media	17
Angiography in intracranial cavernous hemangiomas	81
Fibromuscular hyperplasia of the carotid arteries	90
Embolie complications in cerebral angiography	97
Carotid angiography in cluster headache	177
Retinal and cerebral fat emboli following lymphography with oily contrast media	199
Fibromuscular hyperplasia in children	203
Position of the venous angle in the median sagittal plane	271
Non filling of the ventricular system in encephalography	345
Topometric positions of venous angle in intracranial expansive lesions	353
Scintillation camera and rectilinear scanner for detection of space-occupying intracranial lesions	534
Examination of the facial canal	545
Cannula for injection of contrast medium in cerebral angiography	553

Digestive tract (incl. biliary tract and spleen)

Residual contrast medium in the intestines and side effects during cholecystography	69
Mesenteric adenitis in childhood simulating intussusception	130
Angiographic demonstration of rupture of the spleen	145
Angiographic diagnosis of tumours arising from the pancreatic islets	161
Sialography of the sublingual gland	187
Routine abdominal radiology in health examinations	299
Effect of dextran solutions on intravenous iodipamide toxicity	458
Oral cholecystography — Comparison of 70-mm film and full scale radiography	499

Heart and Vessels (incl. lymphatic vessels)

Normal size of the internal carotid middle and anterior cerebral arteries	1
Arteriographic appearances of phaeochromocytomas	35
Microangiography of the renal vessels in rabbit	49
Angiography in intracranial cavernous hemangiomas	81
Fibromuscular hyperplasia of the carotid arteries	90
Embolie complications in cerebral angiography	97
Histologic staining of contrast filled blood vessels in microangiographed tissues	138
Angiographic demonstration of rupture of the spleen	145
Effect on erythrocytes of large doses of contrast medium in angiocardiology	151
Angiographic diagnosis of tumours arising from the pancreatic islets	161
Carotid angiography in cluster headache	177

Transcaval injection of the portal vein	193
Retinal and cerebral fat emboli following lymphography with oily contrast media	199
Fibromuscular hyperplasia in children	203
Balloon catheters and their percutaneous insertion	209
Arteriovenous fistulae secondary to renal biopsy	218
L'artériographie après cathétérisme percutané par voie artérielle axillaire	241
Traumatic arterial spasm	257
Position of the 'venous angle' in the median sagittal plane	271
Topometric positions of 'venous angle' in intracranial expansive lesions	353
Venous communications of the adrenal glands	369
Semi automatic construction and computer analysis of volume curves and pressure volume curves in cineangiography	413
Phlebographic changes in arteriomegaly	427
Intraarterial administration of bradykinin and hydergine in obstructive arterial disease	449
Effect of dextran solutions on intravenous iodipam de toxicity	458
Lymphography in cardiac arrest, electrical ventricular fibrillation and deep hypothermia	465
Angiographic diagnosis of rejection and tubular necrosis in human kidney allografts	476
Cystosarcoma phyllodes diagnosed by subcutaneous mammary phlebography	494
Occurrence and course of thrombosis following prostatectomy	513

Lungs, Pleura, Mediastinum and Chest walls

Atypical roentgen appearances of the lung in hyaline membrane disease of the newborn	57
Motility of diaphragm in children with bronchial foreign bodies	113
Aspiration biopsy diagnosis of neurogenous mediastinal tumours	289
Cystosarcoma phyllodes diagnosed by subcutaneous mammary phlebography	494

Bones and Joints (incl. soft tissue)

Skull size and ventricular dilatation in subdural hygroma in infants	11
Angulation measurements in supracondylar fractures of the femur	108
Roentgenologic photometric method for bone mineral determinations	305
Synovial lesions in the adult hip joint in rheumatoid arthritis	326
Destruction of the odontoid process due to pyogenic spondylitis	394
Correction of the pelvis in bladder exstrophy	401

Ear, Nose and Throat

Fluid in the maxillary sinus	433
Examination of the facial canal	545

Uro-Genital system

Arteriographic appearances of phaeochromocytomas	35
Fibromuscular hyperplasia in children	203

Double contrast cystography	218
Venous communications of the adrenal glands	225
Angiographic diagnosis of rejection and tubular necrosis in human kidney allografts	332
Hystero-graphy in intrauterine pregnancy and abortion	337
Occurrence and course of thrombosis following prostatectomy	363
	476
	489
	513

RADIOACTIVE ISOTOPES

Experimental isotope renography — Localization of ureteric obstruction	332
Lymph node scanning with ^{199}Au	359
Scintillation camera and rectilinear scanner for detection of space occupying intracranial lesions	534

TECHNIQUE

Microangiography of the renal vessels in rabbit	49
Cine-roentgen equipment for small objects	76
Histologic staining of contrast filled blood vessels in microangiographed tissues	138
Sialography of the sublingual gland	187
Transcaval injection of the portal vein	193
Balloon catheters and their percutaneous insertion	209
Immediate centering and tomographic cut localization by means of roentgen television	236
Simplified densitometry	252
Roentgenologic photometric method for bone mineral determinations	305
Correction of the pelvis in bladder exstrophy	401
Elimination of blur in linear tomography	441
Oral cholecystography — Comparison of 70 mm and full scale radiography	499
Scintillation camera and rectilinear scanner for detection of space-occupying intracranial lesions	534
Cannula for injection of contrast medium in cerebral angiography	553
An enema nozzle	557

CONTRAST MEDIA

Neurotoxicity of roentgen contrast media	17
Residual contrast medium in the intestines and side effects during cholecystography	69
Effect on erythrocytes of large doses of contrast medium in angiocardiology	151
Retinal and cerebral fat emboli following lymphography with oily contrast media	199
Double contrast cystography	337
Effect of dextran solutions on intravenous iodipamide toxicity	458

BOOK REVIEWS

Cerebral angiography	155
Zonography — Narrow angle tomography	156
Diagnostic radiologic instrumentation — Modulation transfer function	157
History and development of radiology in Denmark 1896—1950	158
Röntgendiagnostik der Iliosakralgelenke und ihrer nahen Umgebung	158
Das Röntgenfernsehen — Technische Grundlagen und klinisch röntgenologische Anwendung	159
Dynamic factors in roentgen diagnosis	160
Dosage non destructif de la composante minérale du tissu osseux par densitométrie radiographique	448

List of Authors

(r) indicates 'reviewed only'

Ahlback S 394
Andersen P E 90 203
Andress M R 427
Aclsson A 433

Becker J 513
Bjork L 151 413
Bogren H 81
Boysen E 161
Borgstrom S 513
Brahe Pedersen Chr 545
Brunner S 545
Buchler Fredenksen P 359

Cels A 465
Chudekel N 433
Collett S 394
Cronquist S 11, 97

Dahlgren S 193 289
Del Castillo H 465
Dihlmann W 158 (r)

Edholm P 401 441
Eising H-O 11 97
Ekbon K 177
Ekelund L 218
Ekman B 305
Erikson U 449
Eriksson S 69

Feist J H 160 (r)
Flemming Møller P 158 (r)
Frimann Dahl J 236

Gabrielsen T O 1
Gebauer A 159 (r)
Gillespie H W 299
Guthlin J 257
Greblius N 433
Greitz T 1 177
Groth C G 458

Haase J 534
Hackett R L 476
Hajdu N 130
Haverling M 193, 209
Herting S E 359
Holm Møller S 345
Honore M 489
Huguot J F 241

Ivemark B I 225

Jagt T 359
Jensen C 433
Jensen J Th 337
Jensen R 499
Jeppesen P 359
Jeppsson P G 17

Kaude J 476 499
Kormano M 138
Krayenbuhl H 155 (r)
Kuhl H B 236

Lagergren C 225
Lanner L O 35
Lasser E C 160 (r)
Lea Thomas M 427
Liljequist B 187
Lindahl O 108
Lindgren I 49 332
Lindvall N 225
Lussner J 159 (r)
Ljungquist K G 305
Lofstrom B 458
Lundstrom B 145

Malcla P 332
Margolin F R 57
Mattsson O 76 252, 557
Mena M A 465

Mikaelsson C G 369
Moseley Jr R D 157 (r)
Mouvet W 448 (r)
Movin A 108

Navarro H 241

Olin T 17, 257
Ovenfors C O 193, 289

Palacios E 97
Pedersen M 534
Pfaff W W 476
Probst F P 271, 353, 494

Quiding L 441

Rasmussen K E 199
Robertson B 57
Rosencrantz M 35
Rudhe U 57
Rust J H 157 (r)

Saltzman G F 69, 458, 513
Samuelson L 161
Schott O 159 (r)
Slusher D H 476
Stein U 305
Svalander C 81

Theander G 113

Welander U 187
Wendelin H 49
Westberg G 553
Weston W J 326
Westra D 156 (r)
Wickborn I 81

Yajargal M 155 (r)

List of Supplements to Acta Radiologica

Nos 173—302

(Issued November 1970)

For Suppl Nos 1—172 inclusive, see list issued December 1960, in Vol 54, fasc 6

The supplements are published from time to time and are not included in the subscription rate. Prices and year of publication of numbers already issued are detailed below.

- 173 ERIK ODEBLAD, BJORN WESTIN and SVEN ERIK ENGLUND Disappearance measurements. Theoretical, technical, biological and medical aspects 1959 *Price Sw Kr 30*
- 174 LARS BILLING and ERIK SEVERIN Slipping epiphysis of the hip. A roentgenological and clinical study based on a new roentgen technique 1959 *Price Sw Kr 35*
- 175 ÅKE HANNGREN Studies on the distribution and fate of C^{14} - and T-labelled p amino-salicylic acid (PAS) in the body 1959 *Price Sw Kr 25*
- 176 LARS BJÖRN Cineradiographic studies on the Gallopien tubes in rabbits 1959 *Price Sw Kr 25*
- 177 PEKKA VUORINEN The roentgenographic slit methods. A survey and analysis of procedures based on the use of a narrow bundle of roentgen rays (scanography) 1959 *Price Sw Kr 25*
- 178 BENGT H O ROSENGREN Determination of cell mass by direct λ ray absorption 1959 *Price Sw Kr 25*
- 179 S HULTBERG, O DAHL, R THORAEUS, K J VIKTERLOF and R WALSTAM Halocurie cobalt 60 therapy at the Radiumhemmet. Equipment, technique and dose measurements 1959 *Price Sw Kr 35*
- 180 BENGT LILJA Motor activity of the stomach 1959 *Price Sw Kr 25*
- 181 PER AMUNDSEN The diagnostic value of conventional radiological examination of the heart in adults (Appendix by R G CARPENTER. An account of the statistical analysis of the relative heart volumes of 755 patients in various disease groups) 1959 *Price Sw Kr 20*
- 182 H M TRUBY Acoustico cineradiographic analysis considerations with especial reference to certain consonantal complexes 1959 *Price Sw Kr 35*
- 183 ERIK BOIJSEN Angiographic studies of the anatomy of single and multiple renal arteries 1959 *Price Sw Kr 30*
- 184 GUSTAF NOTTER A technique for destruction of the hypophysis using Y^{90} spheres. A radiologic, endocrine and histologic study 1959 *Price Sw Kr 35*
- 185 BENGT LILIEQUIST The subarachnoid cisterns. An anatomic and roentgenologic study 1959 *Price Sw Kr 35*
- 186 BENGT LILIEQUIST Pontine angle tumour. Encephalographic appearances 1959 *Price Sw Kr 30*
- 187 HOLGER SKOLDBORN On the design, physical properties and practical application of small condenser ionization chambers 1959 *Price Sw Kr 30*
- 188 JENS NIELSEN Anno Actatus Suae LXX. Papers dedicated to Jens Nielsen, professor of radiotherapy at the University of Copenhagen, on his sixtieth anniversary December 19, 1959 *Price Sw Kr 40*

- 189 OLOF DAHL and KARL JOHAN VIKTERLOF Attainment and value of precision in deep radiotherapy. Some fundamentals with special reference to moving beam therapy with 200 and 250 kV roentgen rays and cobalt 60 gamma radiation 1960 *Price Sw Kr 35*
- 190 RUNE SÖREMARK Distribution and kinetics of bromide ions in the mammalian body. Some experimental investigations using $\text{Br}^{82\text{m}}$ and Br^{82} 1960 *Price Sw Kr 30*
- 191 ULF BORELL and INGMAR FERNSTROM Radiologic pelvimetry 1960 *Price Sw Kr 30*
- 192 NILS LINDVALL Renal papillary necrosis. A roentgenographic study of 155 cases 1960 (Out of print)
- 193 PAUL EDHOLM The tomogram. Its formation and content. 1960 *Price Sw Kr 30*
- 194 RAIMO HÄVILÄINEN Pleural calcification as a roentgenologic sign of non-occupational endemic anthophyllite asbestosis. (Mineralogic appendix by OLAVI KUONO) 1960 *Price Sw Kr 25*
- 195 SVEY SCHILLER Roentgenographic studies on epiphyseal growth and ossification in the knee. 1960 *Price Sw Kr 35*
- 196 H. A. HULTBORN and BO TÖRNBERG Mammary carcinoma. The biologic character of mammary carcinoma studied in 517 cases by a new form of malignancy grading 1960 *Price Sw Kr 35*
- 197 LARS R. HOLSTI The mitotic and radioprotective effect of cysteine and lysine in rat 1960 *Price Sw Kr 30*
- 198 OSBORNE BARTLEY The isometric relaxation phase of the left ventricle. An electrokymographic study 1960 *Price Sw Kr 35*
- 199 GUNNAR WILDER VESTBY Vaso-seminal vesiculography in hypertrophy and carcinoma of the prostate with special reference to the ejaculatory ducts 1960 *Price Sw Kr 35*
- 200 BJÖRN NORDENSTRÖM Contrast examination of the cardiovascular system during increased intrabronchial pressure 1960 *Price Sw Kr 30*
- 201 GIOVANNI DI CINRO RISA encephalography and conventional neuroradiologic methods. A comparative study 1961 *Price Sw Kr 35*
- 202 LARS BJÖRK Velopharyngeal function in connected speech. Studies using tomography and sound spectrography 1961 *Price Sw Kr 25*
- 203 S. R. KJELLBERG, B. NORDENSTRÖM, U. RUDHE, V. O. BJÖRK and G. MALMSTRÖM Cardioangiographic studies of the mitral and aortic valves 1961 *Price Sw Kr 30*
- 204 GUNNAR CARLBERGER Kinetics and distribution of radioactive cobalt administered to the mammalian body 1961 *Price Sw Kr 30*
- 205 HANS MOELL Kidney size and its deviation from normal in acute renal failure. A roentgenographic study 1961 *Price Sw Kr 25*
- 206 LEIF HULD HANSEN Micturition cystourethrography with automatic serial exposures. An opinion on the value of the method 1961 *Price Sw Kr 30*
- 207 FINN LUNDVALL Cancer of the vulva. A clinical review 1961 *Price Sw Kr 30*
- 208 ILMARI LINDGREN Anatomical and roentgenologic studies of tuberculous infections in BCG-vaccinated and non-vaccinated subjects with biophysical investigations of calcified foci 1961 *Price Sw Kr 25*
- 209 PER ERIC M. BERGNER The significance of certain tracer kinetic methods especially with respect to the tracer dynamic definition of metabolic turnover 1962 *Price Sw Kr 30*
- 210 P. VUORINEN, P. ANTILA, U. WEGELIUS, A. KALPILA and E. KOIVISTO Renal cortical index and other roentgenographic renal measurements. 1962 *Price Sw Kr 25*

- 212 LARS ANDREN Pelvic instability in newborns with special reference to congenital dislocation of the hip and hormonal factors A roentgenologic study 1962 *Price Sw Kr 30*
- 213 NILS MAGNUS OHLSSON Left heart and aortic blood flow in the dog Precision motion analysis of high speed (270 frames/sec) cinefluorographic recordings 1962 *Price Sw Kr 35*
- 214 BENGT TJERNBERG Lymphography An animal study on the diagnosis of $V \times 2$ carcinoma and inflammation 1962 *Price Sw Kr 35*
- 215 PAAVO KLAMI Periarthrosis calcarea of the shoulder joint Its differentiation from other stiff and painful shoulders 1962 *Price Sw Kr 30*
- 216 P EDHOLM, I FERNSTROM, K LINDBLOM and S I SELDINGER Roentgen television in practice with special regard to puncture examinations 1962 *Price Sw Kr 35*
- 217 FOLKE EDSVYR Carcinoma of the vulva An analysis of 560 patients with histologically verified squamous cell carcinoma 1962 *Price Sw Kr 30*
- 218 P SOILA, M GRONROOS, O KAUPPILA and L PYRKONEN Wasserlösliche, viskosierte wasserlösliche und jodolige Kontrastmittel in der Hysterosalpingographie Vergleichende Untersuchungen 1962 *Price Sw Kr 25*
- 219 STIG SANDMARK Hiatal incompetence Studies on mechanics and principles of examination for hiatus hernia and gastro-oesophageal reflux 1963 *Price Sw Kr 25*
- 220 MAX LUNDBERG Free movements in the temporomandibular joint A cineradiographic study 1963 *Price Sw Kr 30*
- 221 ÅKE NORRHAGEN Selective angiography of the hepatic veins Experimental investigations of basal circulatory dynamics 1963 *Price Sw Kr 35*
- 222 ERLING HAMMER JACOBSEN Genetically significant radiation doses in diagnostic radiology 1963 *Price Sw Kr 35*
- 223 ASTRID BROHULT Alkoxyglycerols and their use in radiation treatment An experimental and clinical study 1963 *Price Sw Kr 30*
- 224 CARL OLOF OVENFORS Pulmonary interstitial emphysema — An experimental roentgen diagnostic study 1964 *Price Sw Kr 35*
- 225 GEORG THEANDER Variation in shape of gallbladder during cholecystography 1964 *Price Sw Kr 30*
- 226 HUGO BOGREN The composition and structure of human gallstones 1964 *Price Sw Kr 30*
- 227 LARS NORDQVIST The sagittal diameter of the spinal cord and subarachnoid space in different age groups — A roentgenographic post mortem study 1964 *Price Sw Kr 25*
- 228 LENNART WICTORIN Bone resorption in cases with complete upper denture — A quantitative roentgenographic photogrammetric study 1964 *Price Sw Kr 30*
- 229 ARNFINN ENGESET Irradiation of lymph nodes and vessels — Experiments in rats, with reference to cancer therapy 1964 *Price Sw Kr 30*
- 230 LARS HOLLENDER Determining the elements of the interior orientation in roentgenography 1964 *Price Sw Kr 30*
- 231 HANS HENRIK HOLM The hydrodynamics of micturition — Examination by means of micro-manometer and uroflowmeter of the hydrodynamic conditions in normal subjects and in patients suffering from obstruction in the posterior part of the urethra 1964 *Price Sw Kr 30*
- 232 EBBE CEDERQUIST Clinical application of whole body counting of ^{86}Sr and ^{45}Ca in patients with and without widespread malignant skeletal disease 1964 *Price Sw Kr 30*
- 233 SVEN PAULIN Coronary angiography — A technical, anatomic and clinical study 1964 *Price Sw Kr 40*
- 234 TROELS MUNKNER The influence of para aminosalicylic acid on the I^{131}I metabolism 1965 *Price Sw Kr 30*

- 235 ANDERS LUNDERQUIST Angiography in carcinoma of the pancreas. 1965 *Price Sw Kr 35*
- 236 RUNE WALSTAM Studies on therapeutic short-distance and intracavitary gamma beam techniques — Physical considerations with special reference to radiation protection 1965 (Out of print)
- 237 KAI SETALA Differences in pharmacodynamic response to colchicine between benign and malignant epidermal hyperplasias — An experimental study in skin tumor resistant mice 1965 *Price Sw Kr 30*
- 238 UNO ERIKSON Circulation in traumatic amputation stumps — An angiographical and physiological investigation. 1965 *Price Sw Kr 35*
- 239 CARL-GUSTAF STANDERTSJOJD-NORDENSTAM The pulmonary circulation during pneumonia — A cineradiographic study 1965 *Price Sw Kr 35*
- 240 ANTTI CEDERBERG Granulocyte distribution in bone marrow, blood and different organs in whole body irradiated rats 1965 *Price Sw Kr 35*
- 241 KAI SETALA Decorporation of radiostrontium Radioactive assay techniques — An experimental study on mice 1965 *Price Sw Kr 30*
- 242 SHINJI TAKAHASHI Conformation radiotherapy — Rotation techniques as applied to radiography and radiotherapy of cancer 1965 *Price Sw Kr 40*
- 243 J Th VAN DER WERFF Radioactive bismuth ²¹²Bi — Experimental studies and clinical applications 1965 *Price Sw Kr 35*
- 244 SAMUEL S KUROHARA Effects of ionizing radiation on creatine metabolism in patients treated for malignancy and in rats 1965 *Price Sw Kr 35*
- 245 PER WESTLING Studies of the prognosis in Hodgkin's disease. 1965 *Price Sw Kr 35*
- 246 SVEN GOTTMAR ERICSSON Quantitative microradiography of cementum and abraded dentine — A methodological and biological study 1965 *Price Sw Kr 35*
- 247 MAURI WILJALLO Lymphographic differential diagnosis of neoplastic diseases 1965 *Price Sw Kr 35*
- 248 SVEN SCHELLER Roentgenographic studies on the ossification of the distal femoral epiphysis. 1965 *Price Sw Kr 30*
- 249 ROAR NISSEN MEYER Castration as part of the primary treatment for operable female breast cancer — A statistical evaluation of clinical results. 1965 *Price Sw Kr 35*
- 250 ELIS BERVEN, SVEN HULTBERG, HANS LUDVIG-KOTTMEIER, ROLF SIEVERT, LARS SANTESSON and BENOT SYLVÉN The first fifty years Radiumhemmet 1910—1937 and King Gustaf V Jubilee Clinic 1938—1960 1965 *Price Sw Kr 30*
- 251 MATS HAVERLING Renal phlebography — An experimental study in the pig 1966 *Price Sw Kr 30*
- 252 GUNNAR WESTBERG Gas myelography and percutaneous puncture in the diagnosis of spinal cord cysts. 1966 *Price Sw Kr 30*
- 253 SVEN IVAR SELDINGER Percutaneous transhepatic cholangiography 1966 *Price Sw Kr 35*
- 254 FIRST NORDIC RADIATION PROTECTION CONFERENCE Proceedings Stockholm 1966 Edited by B. Lidén and Erik Lindgren *Price Sw Kr 35*
- 255 LAWRENCE JOSEPH VAN CURA Application of digital computers in radiation dosimetry 1966 *Price Sw Kr 35*
- 256 HANS LUDÉN Aortography: Fluid dynamics and technical problems 1966 *Price Sw Kr 35*
- 257 HJALMAR BOLIN Contrast medium in kidney during angiography — A densitometric method for estimation of renal function 1966 *Price Sw Kr 30*

- 258 ELISABETH JOHANSSON, PER KOLSTAD and GUNNAR SÖDERBERG Cytologic, vascular, and histologic patterns of dysplasia, carcinoma in situ, and early invasive carcinoma of the cervix 1966 *Price Sw Kr 40*
- 259 PAUL EDHOLM Anatomic angles determined from two radiographic projections — Instrument description and measurement techniques 1966 *Price Sw Kr 40*
- 260 TORSTEN ALMEN A steering device for selective angiography and some vascular and enzymatic reactions observed in its clinical application 1966 *Price Sw Kr 40*
- 261 KAI SETALA, BJÖRN LINDROOS and OTTO NYLSSONEN Cancer chemotherapy studies cytoplasmic barrier in malignant epidermal cells against the effect of colchicine — An electron microscopic study in mice 1966 *Price Sw Kr 25*
- 262 KLAS ROSENGREN Hyaline membrane disease — A radiological investigation in rabbits 1967 *Price Sw Kr 35*
- 263 JAN NILSSON Angiography in tumours of the urinary bladder 1967 *Price Sw Kr 35*
- 264 PER ERIK HEIKEL Postmortal changes of the lung — A roentgenographic, microscopic and bacteriological follow up study on a pediatric series and on animals with experimental pneumonia 1967 *Price Sw Kr 30*
- 265 KAI SETALA, OTTO NYLSSONEN and BJÖRN LINDROOS Ultrastructural changes in benign and malignant epidermal states in mice after topical beta radiation 1967 *Price Sw Kr 30*
- 266 GÖRAN NYLANDER Vascular response to vasopressin as reflected in angiography — An experimental study in the dog 1967 *Price Sw Kr 35*
- 267 JOHAN FOLIN Angiography in renal tumours — Its value in diagnosis and differential diagnosis as a complement to conventional methods 1967 *Price Sw Kr 35*
- 268 EERO TALA Carcinoma of the lung — A retrospective study with special reference to pre diagnosis period and roentgenographic signs 1967 *Price Sw Kr 35*
- 269 CARL O. HENRIKSON Iodine 125 as a radiation source for odontological roentgenology 1967 *Price Sw Kr 35*
- 270 CATIONS IN INTRAVASCULAR CONTRAST MEDIA AND DEVELOPMENT OF SPECIFIC METRIZOATE FORMULAS — PHARMACOLOGIC AND CLINICAL STUDIES Proc Symposia at Copenhagen, November 1964, and Sandefjord, September 1966 1967 *Price Sw Kr 40*
- 271 ERNA TARKIÄINEN Intracostal vein meningoencephalography — A technical, anatomic and clinical study 1967 *Price Sw Kr 35*
- 272 ALLAN LUNDERQUIST Arterial segmental supply of the liver — An angiographic study 1967 *Price Sw Kr 35*
- 273 KAI SETALA, MAX SIIBALA, OTTO NYLSSONEN and ERNA TARKIÄINEN Quantitative three dimensional scintillography of the stomach with technetium (^{99m}Tc) 1967 *Price Sw Kr 30*
- 274 PER BERGQVIST Radiation induced early changes in size and vascularity of cervical carcinoma — A colpophotographic and clinical study 1968 *Price Sw Kr 35*
- 275 SUNE ERICSON The parotid gland in subjects with and without rheumatoid arthritis 1968 *Price Sw Kr 40*
- 276 ROLF JENSEN Anterior teeth relationship and speech — Studies using cineradiography synchronized with speech recording 1968 *Price Sw Kr 35*
- 277 SVEN AHLBÄCK Osteoarthritis of the knee — A radiographic investigation 1968. *Price Sw Kr 35*
- 278 IRÉNE SJÖGREN, KJELL BERGSTROM and HERMAN LODIN Echoencephalography in infants and children Comparison with cerebral pneumography in measuring ventricular size 1968 *Price Sw Kr 35*

- 279 BERTIL JARPLID Radiation induced asymmetry and lymphoma of thymus in mice. 1968 *Price Sw Kr 35*
- 280 ERKKI M. LAASONEN Information transmission in roentgen diagnostic chains — Experimental and clinical studies 1968 *Price Sw Kr 35*
- 281 RASHUS STENSTROM Arthrography of the knee joint in children — Roentgenologic anatomy, diagnosis and the use of multiple discriminant analysis 1968 *Price Sw Kr 35*
- 282 KARL HARLSTEDT Carcinoma of the uterine corpus — Factors bearing on the curability 1968 *Price Sw Kr 35*
- 283 LEO STJERNVALL Pharmacodynamic response of epidermal hyperplasias to topical vinblastine treatment 1968 *Price Sw Kr 35*
- 284 HANS FLOD Distribution and kinetics of labelled vitamin B₁₂ 1968 *Price Sw Kr 35*
- 285 ERKKI HOIVIRO Comparative study of roentgen diagnostic classifications — Computer analysis of 124 496 roentgen reports 1969 *Price Sw Kr 35*
- 286 JØRGEN JENSEN Malformations of the inner ear in deaf children — A tomographic and clinical study 1969 *Price Sw Kr 35*
- 287 PEYTTI J. TASKINEN Radiotherapy and TNM classification of cancer of the larynx — A study based on 1 447 cases seen at the Radiotherapy Clinic of Helsinki during 1936—1961 1969 *Price Sw Kr 35*
- 288 ROBERT T. NASH Decision processes employing radioisotope scanning 1969 *Price Sw Kr 35*
- 289 SIRANA WILJASALO Lymphographic polymorphism in Hodgkin's disease — Correlation of lymphography to histology and duration 1969 *Price Sw Kr 35*
- 290 ULF WELANDER Multicolor combination images in subtraction angiography — A new photographic method and its applications 1969 *Price Sw Kr 40*
- 291 ILONA SCHRECK PUROLA Failure of malignant epidermal cells to respond to vinblastine sulfate — A study in skin tumor resistant mice 1969 *Price Sw Kr 35*
- 292 GIOVANNI RUGGIERO, GIANFRANCO CRISTI and CLAUDIO TREVISAN Clinical aspects of encephalography 1969 *Price Sw Kr 30*
- 293 PEKKA VIRTAMA and TAPIO HELELA Radiographic measurements of cortical bone — Variations in a normal population between 1 and 90 years of age. 1969 *Price Sw Kr 20*
- 294 L. STJERNVALL E. E. NISKANEN and J. TAREKANEN Penetration of cytoplasmic barrier in malignant epidermal hyperplasia by colchicine in dimethyl sulfoxide — A polarization microscopic study in skin tumor resistant mice 1969 *Price Sw Kr 20*
- 295 KAARINA TOURU KAISILA Heart size determination by photofluorography 1970 *Price Sw Kr 35*
- 296 HANS ROYING Otosclerosis — A tomographic-clinical study 1970 *Price Sw Kr 35*
- 297 PER LANGE LAND Population screening for female breast tumours A clinical investigation 1970 *Price Sw Kr 35*
- 298 JOHAN EDGREN Effect of cysteine on chromosome aberrations induced by radiation of human lymphocytes in vitro 1970 *Price Sw Kr 30*
- 299 RUNE SUNDGREN Selective angiography of the left gastric artery 1970 *Price Sw Kr 35*
- 300 NIELS BRØGAARD The lower urinary tract in infancy and childhood — Micturition cinematography with simultaneous pressure flow measurement 1970 *Price Sw Kr 35*
- 301 M. VIKERI Ultrasound examination of pleural plaques — Experimental, pathologic and clinical studies 1970 *Price Sw Kr 35*
- 302 INGEMAR JOELSSON Radiotherapy of carcinoma of the uterine cervix with special regard to external irradiation 1970 *Price Sw Kr 35*

